Software Engineering Institute

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NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

A Survey of Systems Engineering Effectiveness

- Initial Results

Joseph P. Elm
Dennis R. Goldenson
Khaled El Emam
Nicole Donatelli
Angelica Neisa
NDIA SE Effectiveness Committee

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Preface

This report is the result of a collaborative effort between the National Defense Industrial Association (NDIA) Systems Engineering Effectiveness Committee (SEEC) and the Software Engineering Institute (SEI) of Carnegie Mellon University. It is the result of over three years of effort.

While the output of this survey activity is complete in its current form, and needs no further work to find application in the defense industry today, it also suggests some directions for future activities. More research is needed. This work is merely a first step in a continuing effort to understand and measure the impacts of Systems Engineering.

It should be emphasized that the analysis results and graphs described throughout this report depend fully on the mapping of survey questions to associated analysis groupings. When interpreting analysis findings, readers are strongly encouraged to refer to Section 5 of this report where this mapping is defined so the analyses can be considered in appropriate context. Rather than relying on vague definitions or impressions of systems engineering and the activities that comprise it, for which there is no clearly defined consensus across industry, from the perspective of this survey these components are defined by said mapping, based generally on a well-recognized reference standard (CMMI®).

Note that this mapping of responses to analysis areas is itself subject to interpretation or debate (and is indeed a continued topic of discussion even within the SEEC). Different mappings could, to some degree, naturally produce different analyses and findings. To maximize the likelihood of participant responses to the survey, the question set itself was prioritized and shortened, with the result that individual analysis areas are addressed at varying levels of detail.

The SEEC is aware of only one clearly erroneous mapping (in the Validation SE capability), discovered late in the editing, review, and publication process for this report. After some assessment, the impact was not judged to be significant on the resulting analyses or conclusions, but the rework of graphs and text would have been extensive enough to delay promised schedules for delivery of this report to survey participants and other stakeholders—this was determined to be a higher priority.

Summarized simply, the questions, mappings and analyses (imperfect or not) help establish an initial baseline for quantifying the effectiveness of systems engineering and the associated impact on program performance. It is hoped these, too, will be part of an ongoing dialog within the systems engineering community for follow-on work.

NDIA Systems Engineering Effectiveness Committee

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Acknowledgments

This report was created by the authors based upon the collaborative efforts of the Systems Engineering Effectiveness Committee (SEEC) of the National Defense Industrial Association (NDIA) Systems Engineering Division.

Primary contributors to this effort include:

Alan R. Brown [1]	Robert Bruff	Brian Donahue
Nicole Donatelli	Geoffrey Draper	Terry Doran
Khaled El Emam	Joseph Elm	Dennis Goldenson
Sherwin Jacobson	Al Mink	Angelica Neisa
Gordon F. Neary [1]	Brad Nelson [1]	Ken Ptack
Mike Ucchino [1]		

Members of the SEEC Committee include

Dennis Ahearn	Col. Warren Anderson	Marvin Anthony
Ben Badami	David P. Ball	Alan R. Brown[1]
Al Bruns	Robert Bruff	Thomas Christian
John Colombi	Jack Crowley	Greg DiBennedetto
Jim Dietz	Brian Donahue	Terry Doran
Geoffrey Draper	Joseph Elm	Jefferey Forbes
John P. Gaddie	Donald J. Gantzer	Dennis Goldenson
Dennis E. Hecht	Ellis Hitt	James Holton
Sherwin Jacobson	George Kailiwai	Ed Kunay
Dona M. Lee	Jeff Loren	David Mays
John Miller	Al Mink	Gordon F. Neary[1]
Brad Nelson[1]	Rick Neupert	Odis Nicoles
Brooks Nolan	Ken Ptack	Michael Persson[1]
Arthur Pyster	Bob Rassa	James “Rusty” Rentsch
Paul Robitaille	Garry Roedler	Rex Sallade
J. R. Schrand	Sarah Sheard	Jack Stockdale
Jason Stripinis	Mike Ucchino[1]	Ruth Wuenschel
Brenda Zettervall[1]		

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Robert Ferguson	Mike Konrad	Brian Gallagher
Keith Kost	James McCurley	Tom Merendino
Gerald Miller	Mike Phillips	Dave Zubrow

[1] Committee Co-Chair

Executive Summary

The Systems Engineering Division (SED) of the National Defense Industrial Association (NDIA) established the Systems Engineering Effectiveness Committee (SEEC) to obtain quantitative evidence of the effect of Systems Engineering (SE) best practices on Project Performance. The SEEC developed and executed a survey of defense industrial contractors (i.e., suppliers to the government) to identify the SE best practices utilized on defense projects, collect performance data on these projects, and search for relationships between the application of these SE best practices and Project Performance.

The SEEC surveyed a sample of the population of major government contractors and subcontractors consisting of contractors and subcontractors represented in the NDIA SED.

The survey questionnaire was developed using the SE expertise and the broad diversity of experience of the SEEC members. The questionnaire consisted of three sections; one to identify the characteristics of the responding project, a second to assess the project's utilization of SE best practices, and a third to collect measures of Project Performance.

The survey data was collected by the Carnegie Mellon® Software Engineering Institute (SEI) via the Web. Policies ensuring the anonymity of the respondents and the confidentiality of their responses were enforced to protect the competition-sensitive information supplied. Responses sufficient for most analyses were received from a total of 46 projects; another 18 projects provided partial responses useful for basic descriptive purposes. These responses were analyzed by the SEI to identify relationships between the deployment of SE best practices and overall project/program performance. The results of this analysis are published in this report. Only aggregated results are contained in this report; no information traceable to any individual respondent, project, or organization is included.

The questionnaire was designed to assess the project's Systems Engineering Capability (SEC) as measured by its utilization of SE best practices. Project Performance was then assessed based on satisfaction of project cost, schedule, and scope goals. The analysis consisted of

- Processing the respondent's answers to compute a score for that project's ***SEC***
- Numerically ordering the ***SEC*** scores and separating them into three approximately equally sized groups labeled "Lower Capability," "Moderate Capability," and "Higher Capability"[2]
- Processing the respondent's answers to compute a score for that project's performance (***Perf***)
- Numerically ordering the ***Perf*** scores and separating them into three approximately equally sized groups labeled "Lower Performance", "Moderate Performance," and "Best Performance" [2]
- Measuring the strength of the relationship between the Capability and Performance scores.

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[2] Note that the terms "Lower," "Moderate," and "Higher" are relative terms placing each SE Capability score or each Performance score approximately within the lower, middle, or upper third of the range of received responses.

This analysis, as seen in Figure 1, showed that projects with better Systems Engineering Capabilities delivered better Project Performance.

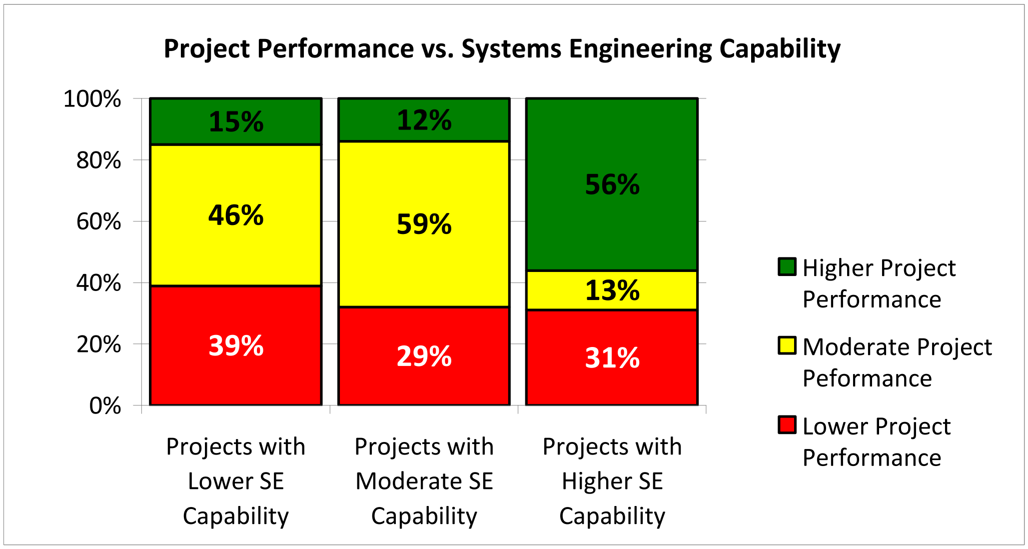


Figure 1: Project Performance Versus Systems Engineering Capability

To better understand the relationship between SE Capability and Project Performance, the questionnaire's assessment of SE Capability looked at 12 areas of SE Capability, addressing the project's utilization of SE best practices in each area. Further details regarding the contents of these process areas are described in the body of this Special Report. As with the relationship between total SE Capability and Performance, the responses were analyzed to identify relationships between Project Performance and the project's use of best practices in each of the process areas. Table 1 summarizes these relationships.

Table 1: Summary of Project Performance Versus Systems Engineering Capability

Supplier's Systems Engineering Capability[3]	Relationship to Project Performance	Relationship (Gamma[4])	Section Reference
Project Planning	Weak positive relationship	+0.13	5.1.3.2
Project Monitoring and Control	Weak negative relationship	-0.13	5.1.3.3
Risk Management	Moderately strong positive relationship	+0.28	5.1.3.4
Requirements Development and Management	Moderately strong positive relationship	+0.33	5.1.3.5
Trade Studies	Moderately strong positive relationship	+0.37	5.1.3.6
Product Architecture	Moderately strong to strong positive relationship	+0.40	5.1.3.7
Technical Solution	Moderately strong positive relationship	+0.36	5.1.3.8
Product Integration	Weak positive relationship	+0.21	5.1.3.9
Verification	Moderately strong positive relationship	+0.25	5.1.3.10
Validation	Moderately strong positive relationship	+0.28	5.1.3.11
Configuration Management	Weak positive relationship	+0.13	5.1.3.12
IPT-Related Capability	Moderately strong positive relationship	+0.34	5.1.3.1

Additionally, the survey examined the relationship between Project Challenge and Project Performance. Project Challenge was measured by factors such as included life-cycle phases, sources of technical challenge, total project effort, inter-organizational complexity, contract value, etc. Table 2 summarizes the relationships for each area.

Table 2: Summary of Project Performance Versus Project Challenge

Project Challenge Factor	Relationship to Project Performance	Relationship (Gamma)	Section Reference
Project Challenge	Moderately strong negative relationship	-0.31	5.1.1

3 Use caution to avoid over-interpreting the meaning of the Systems Engineering Capability (SEC) and Project Challenge categories listed in Table 1 through Table 3. For example, the "Project Planning" category does include elements of project planning, but is not a comprehensive compilation of all project planning activities. To properly understand the listed relationships, please refer to the report sections listed in the last column to better understand the contents of each category.

4 Gamma is a measure of association that expresses the strength of relationship between two ordinal variables, with values near -1 indicating a strong opposing relationship, values near 0 indicating a weak or no relationship (statistical independence), and values near +1 indicating a strong supporting relationship

The survey also examined Project Environment factors that may or may not influence Project Performance. Due to the relatively small sample size and the small number of respondents, the number of projects in each answer category for the Project Environment questions was sufficiently small to reduce the confidence one can have in these findings. Results are presented in this report, but care should be taken not to over-interpret these differences.

Finally, the survey examined the impact on Project Performance of the capabilities of the organization acquiring the project (i.e., the organization issuing and managing the contract to the supplier). Although the survey was not specifically designed to provide a detailed assessment of these Acquirer Capabilities, some responses from the suppliers could be used to develop a rudimentary relative measure of some acquirer capabilities. The scope of the acquirer assessment consisted of only a few questions. Due to this narrow scope, and due to the indirect nature of this assessment (i.e., assessment of acquirers via responses from suppliers), this survey was unable to identify clear relationships between Acquirer Capability and Project Performance.

The moderately strong statistical relationships between Systems Engineering Capabilities and Project Performance shown earlier in this Executive Summary are notable by themselves. However, notably stronger relationships are apparent by combining the effects of more than one of the best practices categories, as shown in Table 3.

Table 3: Project Performance Versus aggregated Systems Engineering Capabilities

Supplier Systems Engineering Capability	Relationship to Project Performance	Relationship (Gamma)	Section Reference
Total Systems Engineering Capability	Moderately strong positive relationship	+0.32	5.1.3.13
Combined Requirements and Technical Solution Capability	Strong positive relationship	+0.49	5.2.3.14
Requirements and Technical Solution Combined with Project Challenge	Very strong positive	+0.63	5.3.1.3

Of course, Systems Engineering Capability alone does not ensure outstanding Project Performance. The survey results show notable differences in the relationship between SE best practices and performance among more challenging as compared to less challenging projects (section 5.3.1). The statistical relationship with Project Performance is quite strong for survey data of this kind when both SE Capability and Project Challenge are considered together (Gamma = 0.63; section 5.1.3.3).

This relationship is illustrated in Figure 2.

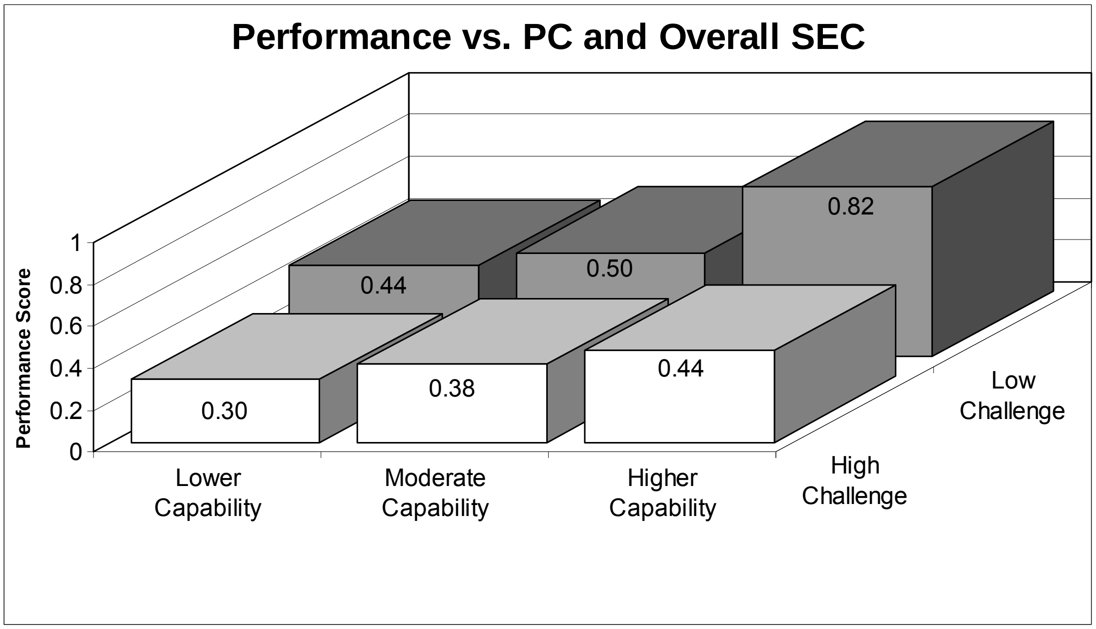


Figure 2: Performance vs. Project Challenge and Overall SE Capability

Abstract

This survey quantifies the relationship between the application of Systems Engineering (SE) best practices to projects and programs, and the performance of those projects and programs. The survey population consisted of projects and programs executed by defense contractors who are members of the Systems Engineering Division (SED) of the National Defense Industrial Association (NDIA). The deployment of SE practices on a project or program was measured through the availability and characteristics of specific SE-related work products. Project Performance was measured through typically available project measures of cost performance, schedule performance, and scope performance. Additional project and program information such as project size, project domain, and other data was also collected to aid in characterizing the respondent's project. Analysis of the survey responses revealed moderately strong statistical relationships between Project Performance and several categorizations of specific of SE best practices. Notably stronger relationships are apparent by combining the effects of more than one the best practices categories. Of course, Systems Engineering Capability alone does not ensure outstanding Project Performance. The survey results show notable differences in the relationship between SE best practices and performance between more challenging as compared to less challenging projects. The statistical relationship between Project Performance and the combination of SE Capability and Project Challenge is quite strong for survey data of this type.

1 Introduction

The mission of the National Defense Industrial Association (NDIA) Systems Engineering Division (SED) is to promote the widespread use of Systems Engineering in the government acquisition process in order to achieve affordable and supportable systems that meet the needs of defense agency and civil agency users. [NDIA 2007] In pursuit of this mission, the NDIA SED tasked the Systems Engineering Effectiveness Committee (SEEC) to research and report on the costs and benefits associated with Systems Engineering practices in the acquisition and development of defense and civil agency systems.

1.1 BACKGROUND

Case studies and surveys are among the various methods used to assess the effectiveness and impact of actions and processes. Both are useful tools, each complementing the other.

Case studies provide an in-depth analysis of one (or a few) specific case(s). This analysis can provide insight into causality (for example, action A caused benefit B). While a case study may be persuasive in its presentation and analysis of information, it remains anecdotal in nature. Because it evaluates only one (or a few) specific case(s), readers may dispute the applicability of the findings to their circumstances and their organizations. Furthermore, the degree to which the findings may be applied and/or extrapolated to different circumstances and different organizations may not be known.

Surveys provide a less comprehensive analysis of a larger number of cases and can be highly useful for showing statistical relationships (wherever action A is taken, benefit B is likely to be found). The results of the surveys are statistical in nature, rather than anecdotal, and their findings are usually more generalizable and applicable to the wider domain of the survey population. Many surveys are self-administered (that is, the respondent reads the survey questionnaire, and generates a response based upon his or her understanding of the question). In such cases, the surveyor must strive to for clarity in the survey questions, since he or she has no opportunity to verify and/or correct the respondent’s interpretations.

1.2 PURPOSE

Case studies and anecdotal reports have shown that properly implemented systems engineering can yield significant benefits for a project. And yet, broadly applicable quantification of these costs and benefits remains elusive. This was the impetus for the formation of the SEEC—to answer the questions

1. What will the application of Systems Engineering practices cost me?
2. What benefits will I gain from the application of these practices?

While one would expect an organization with accurate project cost accounting methods to be able to identify the cost of efforts dedicated to Systems Engineering, this is not always the case. For many projects, Systems Engineering is not an identified, segregated effort with a dedicated budget. Often, Systems Engineering effort is distributed across many project tasks and is planned not independently, but as an element of those tasks. As such, it may be difficult to know both what the original budget was for Systems Engineering, and what actual Systems Engineering expenditures have been. Furthermore, a commonly accepted definition of Systems Engineering does not exist. As such, activities that would be considered Systems Engineering in one organization may be considered as project management or something else in another organization. Thus, even if data on Systems Engineering activities is available, comparison of such data across multiple organizations is not possible.

Quantifying the answer to the second question is even more difficult, since the benefits derived from effective Systems Engineering may be less obvious and less tangible. Some of the benefits take the form of cost avoidance (for example, avoiding rework arising from interface mismatches). Some take the form of improved efficiency (such as defining product and organizational structures that promote effective division of work). Some take the form of improved product performance (for example, better understanding and satisfaction of user needs and key performance parameters).

Because the cost of Systems Engineering effort is not explicitly planned and the benefits are not readily known, the case for the dedication of resources to Systems Engineering activities can be difficult to make. In fact, some projects are tempted to reduce the amount of Systems Engineering applied as a means of reducing schedule and cost. This reduction may take the form of

- reduction (or elimination) of Systems Engineering efforts within the acquiring Program Office
- pressure on the contractor from the acquiring Program Office to reduce Systems Engineering expenditures to limit contract cost
- pressure from the contractor’s management to reduce Systems Engineering expenditures to reduce the bid price.

The intent of this survey was to identify the impact of Systems Engineering efforts by sampling projects at a number of development contractors to identify the degree of statistical relationship between the use of SE best practices applied to a project and the performance of that project.

1.3 SURVEY HYPOTHESIS

A basic tenet of statistical studies is to establish an hypothesis and then test for the validity of that hypothesis. In this particular case, we are asserting that the performance of SE best practices has a measurable, positive impact on program execution, as stated below.

HYPOTHESIS

The effective performance of SE best practices on a development program yields quantifiable improvements in the program execution (e.g., improved cost performance, schedule performance, technical performance).

The alternative to this hypothesis (often referred to as the null hypothesis) is that the performance of SE best practices has no effect (or a negative effect) on program performance. The goal of our survey is to collect and analyze data to choose between these two hypotheses. In theory, this could be accomplished by

1. identifying a number of programs that utilize SE best practices, and collecting their program performance measures
2. identifying a number of programs that do not utilize SE best practices, and collecting their program performance measures
3. comparing the two sets of program performance measures to identify statistically significant differences, if any

In reality, the process is complicated by the following issues:

- We have no reliable way of identifying programs that do or do not use SE best practices.
- Program performance measures are crude measures of actual program performance.
- Program performance measures are influenced by factors other than SE activities (e.g., requirements stability, technical challenge, and other factors).

To address the first of these bulleted issues, we crafted a survey that not only captures program performance measures, but also assesses the use of SE best practices in a quantifiable manner. The use of SE best practices by contractors varies over a continuum from those that do not use best practices to those that use best practices extensively. By collecting data to enable assessment of SE best practice utilization across this continuum, we can look for relationships between SE best practice usage and program performance.

We address the second of these issues by collecting multiple performance measures (such as EVMS data, milestone satisfaction data, and others) and looking for the degree of agreement between these measures.

We address the third of these issues through the assertion that many of the other factors that influence program performance are uncorrelated with the use of SE best practices. For example, there is no reason to believe that contractors that use SE best practices are blessed with programs having contracted requirements of better quality than are contractors that do not use SE best practices. This assertion is also tested in the survey by collecting measures of some of these other factors, enabling the evaluation of the asserted orthogonality.

2 Survey Development

2.1 STEP 1: DEFINE THE GOAL

The role of the SEEC is defined on the NDIA Web site as follows:

> "… [The Systems Engineering Effectiveness] Subcommittee attempts to identify those key critical skills and tools that are essential for implementation of a robust Systems Engineering process. It works to identify success-oriented approaches to systems engineering, and help promote these concepts throughout industry and the department of defense. …"

The identification of critical skills, tools, and success-oriented approaches will not aid projects if they do not use them; and they will not use them unless they are convinced that their benefits exceed their cost. Thus, the goal of this survey was:

> **Goal**: Identify the degree of statistical association between the use of specific Systems Engineering practices and activities on projects, and quantitative measures of Project Performance.

2.2 STEP 2: CHOOSE THE SURVEYED POPULATION

The second step was to choose the population to be included in the survey. As this survey activity was sponsored by the NDIA, the SEEC elected to focus primarily on projects involving defense and other government agencies. Thus, candidate groups for inclusion in the survey included

- government program offices (civil and defense agencies)
- major government contractors
- subcontractors to major government contractors.

The parameters of the study could vary considerably based upon the inclusion or exclusion of each of these groups. Additionally, a means of sampling within these groups was also needed.

The consensus of the SEEC was that, among these groups, the impact of SE would be greater among the contractors and subcontractors than at the program offices. Furthermore, we believed that data availability would be higher in the contractor and subcontractor groups. Thus, the SEEC chose to direct this survey at a population consisting of major government contractors and subcontractors. Although this population is quite large, consisting of thousands of suppliers, the member companies of the NDIA Systems Engineering Division (SED) are a representative subset of this population. The NDIA SED maintains a roster of the 485 "active" members (that is, those who have recently attended NDIA SED meetings). After filtering this list for organizations that supply products (as opposed to services) to defense and government acquirers, the SEEC produced a list of 50 companies to invite to participate in the survey. The intent of the survey was to

collect data at the project level (rather than at the organizational level); thus, each of these 50 organizations could contribute multiple projects to participate in the survey.

Surveys of other populations (i.e., government program offices) may be conducted in the future, if warranted.

2.3 STEP 3: DEFINE THE MEANS TO ASSESS USAGE OF SE PRACTICES

The third step was to define the methods used to assess the application of SE practices to projects. While various SE models, standards, and so forth can inform this decision (such as CMMI-SE/SW, EIA 632, MIL-STD-499B, IEEE-STD-1220, ISO/IEC-15288, and others), this effort was hampered by the fact that a widely accepted definition of what constitutes SE does not exist. To overcome this obstacle, the SEEC chose to survey specific activities that would normally be regarded as elements of SE. The survey analysis then examines the relationships between these activities and overall Project Performance. Thus, for any activity that did not fit a particular reader's preferred definition of SE, the analysis results for that activity could be ignored. In general, the focus of the SE practice assessment was placed on identifying tangible artifacts of SE activities.

The SEEC chose to base this assessment primarily upon the Capability Maturity Model Integration (CMMI) due to the SED's sponsorship of this model, as well as the SEEC's familiarity with it. Starting with the CMMI-SE/SW/IPPD Model v1.1, we identified the work products that, in the judgment of the SE experts on the committee, result from Systems Engineering tasks. The presence of these work products provides an indication of the magnitude of the Systems Engineering activities performed on the project. Questions were worded to search for the content of these suggested work products, rather than the specified work products themselves, thereby enabling the reporting project to accurately represent their system engineering activities, regardless of the titles or format of their specific work products.

This approach enabled us to analyze relationships between Project Performance and Systems Engineering work products both individually and in ensemble, searching for those work products most closely tied to project success.

The process of identifying Systems Engineering work products was as follows:

1. **Extract all listed work products from the CMMI.**
   The CMMI SW/SE/IPPD v1.1 consists of 614 practices needed to satisfy 179 goals organized into 25 process areas. The model also lists 476 typical work products produced by these practices. While this list of work products is not all-inclusive, it provides a reasonable framework that can be used to organize a search for Systems Engineering artifacts.
2. **Identify work products that (in the judgment of the SEEC) result from Systems Engineering activities.**
   Filter these work products to extract those that are (in the judgment of the SEEC SE experts) the result of activities that would normally be classified as Systems Engineering. Developing a firm definition of what is and what is not Systems Engineering is not critical to this process. By looking for defined work products resulting from defined practices, we eliminate the subjectivity of a Systems Engineering definition. At the end of the analysis phase of the sur-

vey, we will have related Project Performance with these defined work products and practices. If we choose to define Systems Engineering as encompassing these practices and work products, then we can relate Project Performance to this definition of Systems Engineering. In the event that a particular reader of this analysis disagrees with that definition of Systems Engineering, it will still be possible for them to examine the relationship between Project Performance and the defined practices and work products.

As a result of this filtering process, the SEEC has identified a subset of 87 practices needed to satisfy 31 goals organized into 14 process areas. These practices produce 199 work products.

3. **Extract those work products that are (in the judgment of the SEEC) most significant.** In a survey such as this, one must be concerned with the demands placed upon the potential respondents. If they are asked for information that is not readily available, or are expected to spend a significant amount of time to complete the questionnaire, the response rate may drop precipitously. For this reason, it is not practical to address all 185 work products identified in the previous process. To shorten the questionnaire, it is necessary to address only the most significant of these work products. Significance is defined as

   - those work products that are thought (in the judgment of the SEEC SE experts) to have the greatest impact on the project
   - those work products that are thought (in the judgment of the SEEC SE experts) to have the greatest ability to discriminate between projects that have effective Systems Engineering, and those that do not

   As a result of this filtering process, the SEEC has identified a subset of 45 practices needed to satisfy 23 goals organized into 13 process areas. These practices produce 71 work products.

This process is illustrated in Figure 3; a summary of the results are found in Table 4; and the details of the process and its outcome are found in Table 4.

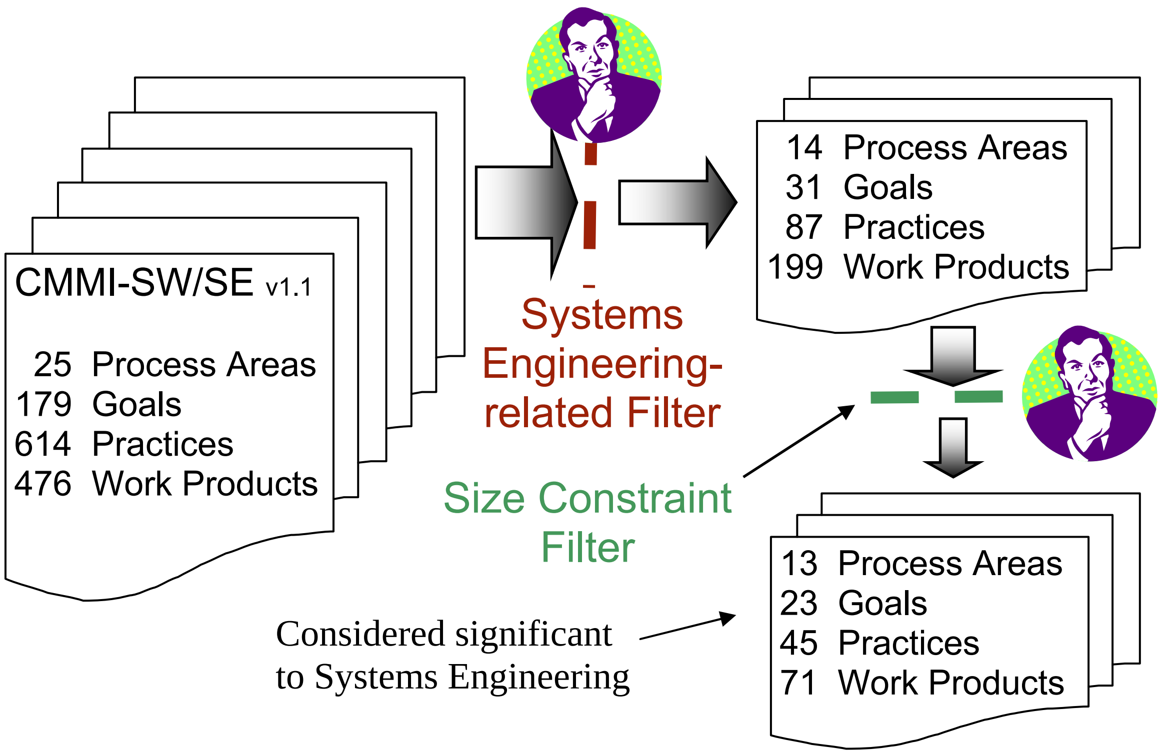


Figure 3: SE Characterization Process

PROCESS AREAS	CMMI SW/SE Total						SE Related						Significant SE					
	Specific			Generic			Specific			Generic			Specific			Generic		
	Goals	Practices	Work Products	Goals	Practices	Work Products	Goals	Practices	Work Products	Goals	Practices	Work Products	Goals	Practices	Work Products	Goals	Practices	Work Products
PROCESS MANAGEMENT																		
Organizational Process Focus	2	7	14	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Organizational Process Definition	1	5	11	5	17	0	1	1	1	0	0	0	1	1	1	0	0	0
Organizational Training	2	7	13	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Organizational Process Performance	1	5	5	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Organizational Innovation and Deployment	2	7	11	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
PROJECT MANAGEMENT																		
Project Planning	3	14	52	5	17	1	2	7	22	1	1	1	2	3	9	1	1	1
Project Monitoring and Control	2	10	11	5	17	0	2	7	0	0	0	0	2	6	0	0	0	0
Supplier Agreement Management	2	7	26	5	17	0	1	1	5	0	0	0	0	0	0	0	0	0
Integrated Project Management	4	13	46	5	17	0	1	3	14	0	0	0	1	2	3	0	0	0
Risk Management	3	7	16	5	17	0	2	3	6	0	0	0	2	3	6	0	0	0
Integrated Teaming	2	8	25	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Integrated Supplier Management	2	5	16	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Quantitative Project Management	2	8	23	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
ENGINEERING																		
Requirements Management	1	5	13	5	17	1	1	5	13	1	1	1	1	4	9	0	1	1
Requirements Development	3	12	28	5	17	0	3	10	28	0	0	0	3	4	8	0	0	0
Technical Solution	3	11	30	5	17	1	3	11	30	1	1	1	2	7	12	1	1	1
Product Integration	3	9	27	5	17	0	2	5	16	0	0	0	1	1	1	0	0	0
Verification	2	8	24	5	17	0	2	9	20	0	0	0	2	5	10	0	0	0
Validation	2	5	16	5	17	0	2	4	11	0	0	0	1	1	2	0	0	0
SUPPORT																		
Configuration Management	3	7	16	5	17	0	3	7	16	0	0	0	3	5	7	0	0	0
Process and Product QA	2	4	13	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Measurement and Analysis	2	8	12	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Decision Analysis and Resolution	1	6	7	5	17	0	1	6	7	0	0	0	0	0	0	0	0	0
Org'l Environment for Integration	2	6	15	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Causal Analysis and Resolution	2	5	6	5	17	0	2	5	7	0	0	0	0	0	0	0	0	0
TOTAL	54	189	476	125	425	3	28	84	196	3	3	3	21	42	68	2	3	3

Table 4: Systems Engineering Work Product Selection

2.4 STEP 4: DEFINE THE MEASURED BENEFITS TO BE STUDIED

The object of this study is to provide quantitative assessment of the value of SE practices. To accomplish this, we need quantitative measures of Project Performance. In order to maximize the availability of data from the participants, we utilized measures common to many organizations. Measures of Project Performance included

- EVMS cost performance index (CPI)
- EVMS schedule performance index (SPI)
- Percent of key performance parameters (KPP) satisfied
- Percent of requirements satisfied
- Percent of available award fees received

Respondents were asked to provide data for any or all of these measures.

2.5 STEP 5: DEVELOP THE SURVEY INSTRUMENT

Defining characteristics of the survey instrument included

- **integrity (**Respondents were assured that the results of the survey would be used only for the stated purposes of the SEEC.)
- **confidentiality** (Respondents were guaranteed that their responses were kept in confidence.)
- **self-administration (**Respondents were able to execute the survey instrument independently, without intervention or involvement of the SEEC.)
- **self-checking** (The questionnaire included cross-checks to ascertain consistency and validity of responses.)

The survey instrument consisted of 142 questions in three sections.

The first section gathered information used to characterize the responding project. Fifty-five questions characterized the projects in terms of

- project size (resources, value, etc.)
- project stability
- customer category
- end-user category
- application domain
- technology domain
- project status (current life cycle phase, percent complete, etc.)
- project team prior experience
- organizational experience
- organizational process focus
- process improvement activities

The second section collected information regarding the performance of Systems Engineering activities and the production of Systems Engineering artifacts. Sixty-five questions measured Systems Engineering performance in the following areas:

- process definition
- project planning
- risk management
- requirements development
- requirements management
- trade studies
- interfaces
- product structure
- product integration
- test and verification
- validation
- configuration management

Most questions in this section were structured in the form of an assertion regarding the project being surveyed:

This project has a <*work product*> with <*defined characteristics*>

where: <*work product*> references one of the CMMI work products identified for inclusion in the survey

<*defined characteristics*> address the contents of the work product

The respondent was then asked to identify his level of agreement with this assertion, choosing from choices of strongly disagree, disagree, agree, or strongly agree. Four response options were chosen to force respondents to "take a position," rather than choose a neutral response.

The third section collected information on Project Performance using 22 questions.

- earned value
- award fee
- milestone satisfaction
- technical requirements satisfaction
- problem reports

Many of these questions asked for quantitative data from the project.

2.6 STEP 6: DESIGN THE SURVEY EXECUTION PROCESS

A primary objective of the survey execution process was to maximize the number of qualified responses. This was accomplished in two steps:

- optimize sampling
- maximize response rate

Sample size was maximized using the resources of NDIA to reach a broad constituency, as discussed in Section 2.2. The intent was to reach a significant percentage of the projects being executed by these organizations.

Three factors were used to maximize response rate.

First, we made responding to the survey simple and convenient by using the Web. To participate, a respondent merely had to obtain an online account from the survey server, log in, and complete the survey.

Second, we established data-handling policies to mitigate respondents' concerns about confidentiality. Some organizations were expected to be reluctant to respond due to the survey's request for competition-sensitive information identifying Project Performance. The following principles of confidentiality, trustworthiness, and security were deployed throughout the survey and clearly communicated to all participants:

- Data would be used only for the stated purposes of the survey.
- Data would be collected and handled by a trusted organization.
- All responses would be collected anonymously. The survey would not solicit information to identify people, projects, or organizations. Furthermore, all respondents would be solicited by proxy, with no contact between the respondents and the surveyor
- Data would be collected and stored securely in an encrypted format.
- Data presented in reports would include only aggregate data and would not include any information traceable to any person, project, or organization.

The intent was to convince respondents that they could respond honestly to the survey questions, without fear of exposing critical information.

Respondents were identified and solicited by proxies within each organization. The use of proxies ensured that respondents were contacted only by members of their own organization. Our expectation was that this would improve the response rate. However, at the same time, the use of proxies precluded the surveyors from soliciting respondents, from expediting responses, and from knowing who had responded. Instead, the surveyors had to rely upon the proxies for these efforts. This forced the SEEC to develop a communication and survey execution process as shown in Figure 4.

Third, the organizations and respondents needed an incentive to respond. We were asking them to spend time and effort responding to the survey. In spite of all of our arrangements for security and anonymity, we were asking them to take a risk, albeit a small one, in exposing competition-sensitive information. Some reward for participation was needed; altruism to advance understanding of the field of Systems Engineering would not be sufficient. But offering some type of reward to anonymous participants was a difficult task.

The solution was to offer information and knowledge as a reward for survey participation. If successful, the survey would provide a benchmark for SE performance among a broad range of government suppliers. Organizations could compare themselves against this benchmark and develop process improvement plans to obtain a competitive advantage. Access to this benchmark information would be offered as a reward for participating in the survey. Survey participants would receive access to the aggregated survey data immediately upon its release. The data would be withheld from the broader public for one year. The Web-based nature of the survey execution also

made it possible to provide this information to the respondents even while maintaining their anonymity. To participate in the survey, the respondents applied to the SEI Web server for an account name and password; a password that they could then change. With this account name and password, they could log in to the Web server and complete the survey in complete anonymity. After completion of the survey analysis, the report could then be posted on the Web server accessible only to those with account names and passwords from survey completion. In this manner, respondents could acquire access to the report without loss of anonymity.

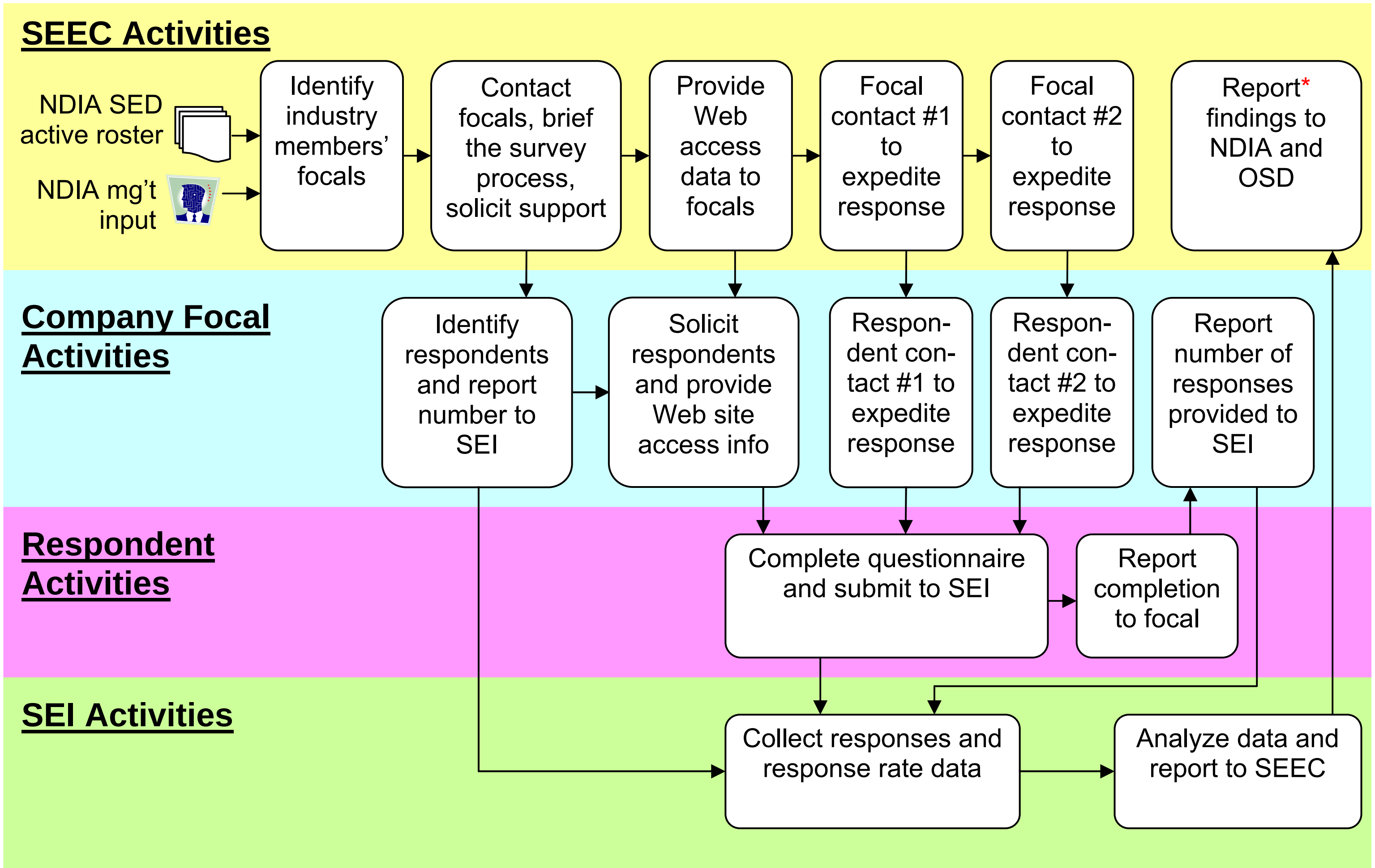


Figure 4: Survey Execution Method

3 Survey Instrument Testing

3.1 STEP 7: PILOT THE SURVEY EXECUTION

Members of the SEEC presented the survey to program staff within their organizations for testing. The focus of this testing was fourfold:

1. Verify the clarity and understandability of the survey questions.
2. Assess the time needed to complete the questionnaire.
3. Verify the operability and reliability of the Web-based collection process.
4. Verify the clarity and understandability of the survey instructions.

The responses represented the characteristics of real programs, verifying that the Web-based collection process worked effectively. We also held follow-up discussions with the beta respondents to verify that they understood the questions and responded appropriately. In this manner, we verified that both the survey instructions and the survey questions were clear and understandable. Finally, we asked the beta respondents to keep track of the amount of time required to complete the survey (we wanted the time kept below an hour—anything more would likely reduce the response rate significantly).

3.2 STEP 8: INCORPORATE FINDINGS FROM THE PILOT

Results of the pilot testing showed the following:

1. The pilot respondents found the survey questions to be both clear and understandable. Discussions with the respondents did not uncover any misinterpretations.
2. The time needed to complete the questionnaire varied considerably among the respondents. Some completed the questionnaire in as little as 30 minutes. Others required in excess of three hours.
3. The Web-based collection process experienced a number of difficulties during the pilot.
4. The survey instructions were found to be clear and understandable.

The SEEC addressed the response time and the Web-based collection issues.

Through discussions with the pilot respondents, the SEEC investigated the sources of completion time variability. Many of the questions within the questionnaire require multiple-choice responses. In most cases, these were found to be quickly and easily answerable. The wide variation in completion times was found to arise from questions requiring a numeric response. These questions were found predominantly in the first section (Project Characterization) and third section (Project Performance) of the questionnaire. The information provided by these types of questions was thought to be very valuable. However, when considering the difficulty in responding to these questions, the SEEC recognized that changes were needed.

- Some respondents felt that asking for a numeric response inferred a heightened request for precision. Some of the excessive response time was spent in researching the “exact” numeric value to be provided. In reality, the purposes of this survey could be served with responses of low to moderate precision. To address this finding, some of the questions were reformatted to “quantize” the responses. Instead of asking for a numeric response, the respondent was asked to choose among pre-defined ranges of numeric responses. This clearly indicated our intent regarding precision, and significantly reduced the time required to complete these questions.
- Some of the questions soliciting numeric responses were simply too difficult to answer for some of the respondents. The information being requested was not readily available, and required too much research to find. While we felt that the requested information would add value to the survey, when balanced with the anticipated reduction in response rate resulting from the difficulty in responding, we chose to eliminate many of these questions.

While the total number of questions remained essentially unchanged, responses to the questions were substantially simplified. Additional pilot testing showed that completion time for the revised questionnaire ranged from 30 minutes to 1 hour. This was accepted by the SEEC.

During the pilot testing, a number of issues were found with the Web-based collection process. In some cases, the respondent’s network security settings prevented them from gaining access to the survey portal and the survey Web sites. In some cases, Web browser incompatibilities compromised the respondent’s ability to participate. In some cases, Web server errors prevented online respondents from resuming an interrupted response session as planned. All of these issues were researched, resolved, and tested during the pilot phase.

The resulting survey instrument can be seen in APPENDIX B.

4 Survey Execution

4.1 SOLICITING RESPONDENTS

As noted above, the surveyors contacted the respondents only through proxies to protect their anonymity. After the organizations to be surveyed were identified (see Section 2.2), the SEEC searched the NDIA SED “active” roster to identify contacts within each organization, with the intent of finding someone to act as both an advocate for the survey, as well as a proxy to identify, contact, and interface with respondents within the organization. The SEEC also collaborated with other organizations (such as AIA, IEEE) to identify these advocates. Criteria for selection of these designated “focals” were as follows:

Organizational criteria	Focal criteria
• participant in the supply chain of the Department of Defense (DoD) • delivering products to the DoD • major operations with the United States • current member of NDIA	• holds a senior management position within the organization. • has access to project managers engaged with defense contracts throughout the entire organization. • has sufficient influence within the organization to encourage project managers to participate in this survey. • recognizes the importance of Systems Engineering and supports this survey activity.

The survey was first introduced to the NDIA SED at the August 2005 division meeting. Subsequently, the SEEC proceeded to contact the candidate focals at the 50 organizations identified in Section 2.2. Contacts were made via face-to-face, telephone, and email to explain the purpose and the principles of this survey, and solicit their support.

Of the contacts identified from the NDIA SED Active Members list, approximately 8% were unable to be contacted; some due to inaccurate contact information, some due to mergers and acquisitions.

Another 6% declined to participate in the survey. One focal cited a continuing concern about data confidentiality. Another noted that he felt no incentive to participate. A third cited a general mistrust of surveys.

The SEEC contacted the remainder of the respondents repeatedly. Most agreed to participate. A few were non-committal. Ultimately, a data package was sent to the focals (see APPENDIX C). This data package consisted of

- a letter of invitation from NDIA
- the survey non-disclosure/privacy policy
- instructions on selecting projects to participate in the survey
- instructions to the respondent

- definition of terms

The instructions to the focals were to

- identify appropriate respondents within their organization for the survey
- report the number of identified respondents to the SEI
- contact the identified respondents, and solicit their participation in the survey
- periodically expedite respondents
- periodically report progress (i.e., the number of responses submitted) to the SEI

4.2 RESPONDING TO THE SURVEY

The SEI prepared to collect anonymous and confidential questionnaire responses from the respondents via the survey Web site. The Web site was developed in a manner that minimized the burden on the respondents. Upon logging on, the respondent received a unique and randomly generated URL at which he could access a copy of the questionnaire. The respondent could access the online questionnaire at the uniquely assigned URL received from the survey portal. Access to this secure site required both knowledge of the URL and a user-defined password. In this manner, only the respondent could access their assigned Web site. The respondent could then complete the questionnaire online, saving his or her results incrementally. At any time, the respondent could exit the Web site without losing the data saved to date. In this manner, the respondent could complete the questionnaire over multiple sessions. On completion of the questionnaire, the respondent notified the survey server by clicking on the ‘Submit’ button.

The SEI began to receive responses shortly after the focals were contacted.

As with any survey, response expediting was necessary. The solicitation of respondents via proxies complicated this process. With the actual respondents unknown to the SEEC, the SEEC could only ask the focals to expedite the respondents. About two weeks after the start of data collection, the SEEC emailed the focals, asking them to

- check with project leaders to see which have responded
- expedite non-responders
- notify SEI of the number of projects which have responded to date

This expediting effort was repeated approximately two weeks later and again two weeks after that.

Obtaining response data from the focals was not highly effective. Our intent was to keep track of response rates by identifying the number of respondents solicited by each focal, and the number of responses reported complete by each focal. Even after numerous contacts of the focals, we were unable to collect sufficient data to support this goal.

The survey Web server accepted responses from August 10, 2006 until November 30, 2006. During this period 64 surveys were collected. Upon review of the responses, it was clear that several were initiated but not completed. These were discarded, resulting in 46 valid survey responses.

5 Analysis

The primary survey hypothesis has been stated as follows:

> The effective performance of SE best practices on a development program yields quantifiable improvements in the program execution (for example, improved cost performance, schedule performance, technical performance).

Mathematically, we can state this as

$$Perf = f\,(PC, PE, SEC, AC)$$

where:	Project Challenge	***PC***
	Project Environment	***PE***
	Systems Engineering Capability	***SEC***
	Acquirer Capability	***AC***
	Project Performance	***Perf***

More detailed descriptions of each of these factors are found within this section.

Our goal is to identify the impact of ***PC***, ***PE***, ***SEC***, and ***AC*** upon ***Perf***. We can do this by identifying the relationships among each of these factors and ***Perf***. The primary objective is to identify the statistical association between ***SEC*** and ***Perf***. We will consider ***AC***, ***PE***, and ***PC*** as factors moderating these primary relationships.

Each of these measures is derived by combining the responses for a set of conceptually related questions. Because the individual questions can be interpreted somewhat differently by different survey respondents, combining the responses into an overall composite measure reduces the unreliability associated with any single question [Guilford 1954]. These composite measures are weighted, summed indices of the responses to each set of questions from each participating project. For example, many of the response categories range ordinally from “disagree strongly” to “agree strongly.” The projects’ answers are scored as 1 through 4 respectively and then summed. Since the number of component items varies for each of the composite measure, the scores are normalized to allow consistent interpretation of their meaning. Much like student grade point averages, the composite scores are divided by the number of questions answered. The composite scores thus are constrained to range between 1 through 4.[5] Calculating the composite scores in this manner provided sufficient variation to enable meaningful statistical comparisons.

The Project Challenge (***PC***) questions address a number of diverse issues contributing to the difficulty of a project; issues such as project size, project complexity, technology precedents, and others. All of these factors are combined into a single ***PC*** measure, with the intent of examining the

5 Such a normalization procedure is appropriate for ordinal data since the component items fall in the same constrained range. Since the fractional differences cannot be interpreted additively, the composite scores then are split into two or three groupings as appropriate for the data analysis. (e.g., “Lower,” “Moderate,” and “Higher” groupings

impact of the project difficulty upon ***Perf*** and the relationships between ***SEC*** and ***Perf*** (see Section 5.1.1)

The Project Environment (***PE***) measures address factors other than Project Challenge and Systems Engineering Capability that could influence Project Performance. These factors include the acquiring organization, the end user, the position in the systems hierarchy, the deployment environment, the contract type, the percent of effort dedicated to Systems Engineering, the development organization's CMMI-related capabilities ($\boldsymbol{PE_{CMMI}}$), the development organization's process improvement efforts ($\boldsymbol{PE_{IMP}}$), and the development organization's prior experience ($\boldsymbol{PE_{EXP}}$). The nature of these ***PE*** elements is sufficiently diverse that it is pointless to attempt to combine them into a single ***PE*** measure. Instead, the impact on Project Performance of each of the PE elements was evaluated individually (see Section 5.1.2).

The questionnaire was designed to permit the Systems Engineering Capability (***SEC***) measure to be decomposed into 12 measures of SE Capability in specific process areas:

IPT-Based Capability	($\mathbf{SEC}_{IPT}$)	Section 5.1.3.1
Project Planning	($\mathbf{SEC}_{PP}$)	Section 5.1.3.2
Project Monitoring and Control	($\mathbf{SEC}_{PMC}$)	Section 5.1.3.3
Risk Management	($\mathbf{SEC}_{RSKM}$)	Section 5.1.3.4
Requirements Development and Management	($\mathbf{SEC}_{REQ}$)	Section 5.1.3.5
Trade Studies	($\mathbf{SEC}_{TRADE}$)	Section 5.1.3.6
Product Architecture	($\mathbf{SEC}_{ARCH}$)	Section 5.1.3.7
Technical Solution (= SEC_{TRADE} + SEC_{ARCH})	($\mathbf{SEC}_{TS}$)	Section 5.1.3.8
Product Integration	($\mathbf{SEC}_{PI}$)	Section 5.1.3.9
Verification	($\mathbf{SEC}_{VER}$)	Section 5.1.3.10
Validation	($\mathbf{SEC}_{VAL}$)	Section 5.1.3.11
Configuration Management	($\mathbf{SEC}_{CM}$)	Section 5.1.3.12

With this decomposition, it is possible to look at more specific relationships between these Systems Engineering Capability factors and Project Performance. As noted previously, the work products identified in CMMI were used as the basis for this survey. Thus, the partitioning of the ***SEC*** responses into categories similar to CMMI Process Areas is sensible. Even though the linkage between this survey and CMMI is strong, be advised that although the names of the survey categories resemble those of the model, they are not perfectly aligned. The survey categories do not contain all aspects of the similar CMMI Process Areas. Furthermore, in many cases, they contain extensions that are not contained within the model. As such, take care not to "over-interpret" the relationship between the survey results and CMMI.

The Acquirer Capability (***AC***) measure addresses the impact of the acquirer's capability upon Project Performance. Because the survey respondents are the project suppliers, and not the project acquirers, any information gathered regarding the acquirers is second-hand information; that is, it is an evaluation of the acquirer from the perspective of the supplier. Nevertheless, there are a few parameters that can be measured to imply Acquirer Capability; parameters such as

- acquirer's participation on Integrated Project Teams (IPTs)
- acquirer's provision of a Systems Engineering Plan (SEP)
- quality of system requirements
- completeness of system requirements

- stability of system requirements

Although this survey was not specifically designed to assess the capabilities of the acquirers, these parameters can be combined to develop a rudimentary measure of Acquirer Capability (***AC***) (see Section 5.2.4).

Finally, Project Performance (***Perf***) can be measured and decomposed into:

Cost Performance	($\boldsymbol{Perf_C}$)
Schedule (Duration) Performance	($\boldsymbol{Perf_D}$)
Scope Performance	($\boldsymbol{Perf_S}$)

The relationship between project cost, schedule, and scope is well known to project managers, and is commonly referred to as the “iron triangle,” reflecting the fact that project manager can often modify the value of one of these parameters, but only at the expense of the other two. For example, a project manager’s election to reduce project cost will have adverse impacts upon the project schedule and the achieved scope of the project. As such, looking for relationships between ***SEC*** and the individual components of ***Perf*** (i.e., $\boldsymbol{Perf_C}$, $\boldsymbol{Perf_D}$, and $\boldsymbol{Perf_S}$) would not be as useful as looking for relationships between ***SEC*** and a composite Project Performance variable combining all three of these components (see Section 5.1.5.4).

5.1 RESPONDENT PROFILE

To profile the responding project, the survey requested information about

- the project
- the product resulting from the project
- the contract establishing the project
- the organization executing the project
- the Systems Engineering practices deployed on the project
- Project Performance data

Responses were analyzed to identify Project Challenge, Project Environment, Project Systems Engineering Capability, and Project Performance.

Responses are presented as distribution graphs showing the frequency of each response, as seen in Figure 5 and Figure 6. Figure 5 is an example of the results from a single question. It has the following characteristics:

- The horizontal axis shows the survey’s available response choices
- The vertical bars represent the percentage of total respondents selecting each response choice

Figure 6 is an example of the results of a composite score calculated from the combination of responses to multiple related questions. It has the following characteristics:

- The horizontal axis represents the range of the composite score, usually scaled from 1 to 4. For a graph depicting an SE Capability, 1 would represent a low capability and 4 would rep-

resent a high capability. For a graph depicting Project Challenge, 1 would represent low challenge while 4 would represent high challenge.

- The horizontal range of 1 to 4 is divided into a number of equally sized bins. The vertical bars represent the percentage of respondents whose score falls within the range of each bin.

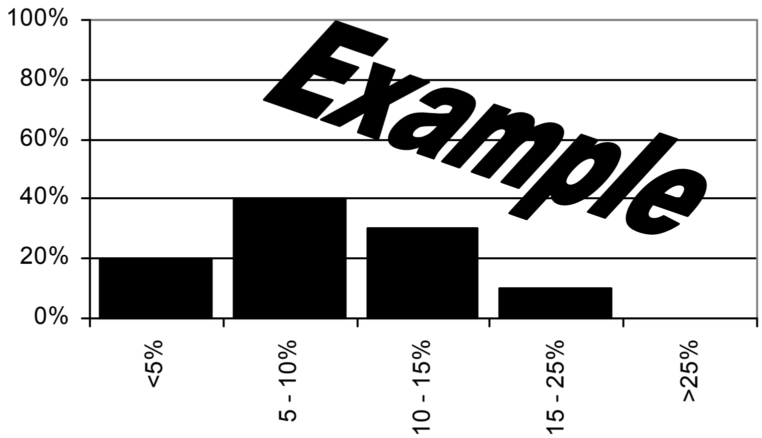


Figure 5: Example Distribution Graph for an Individual Question

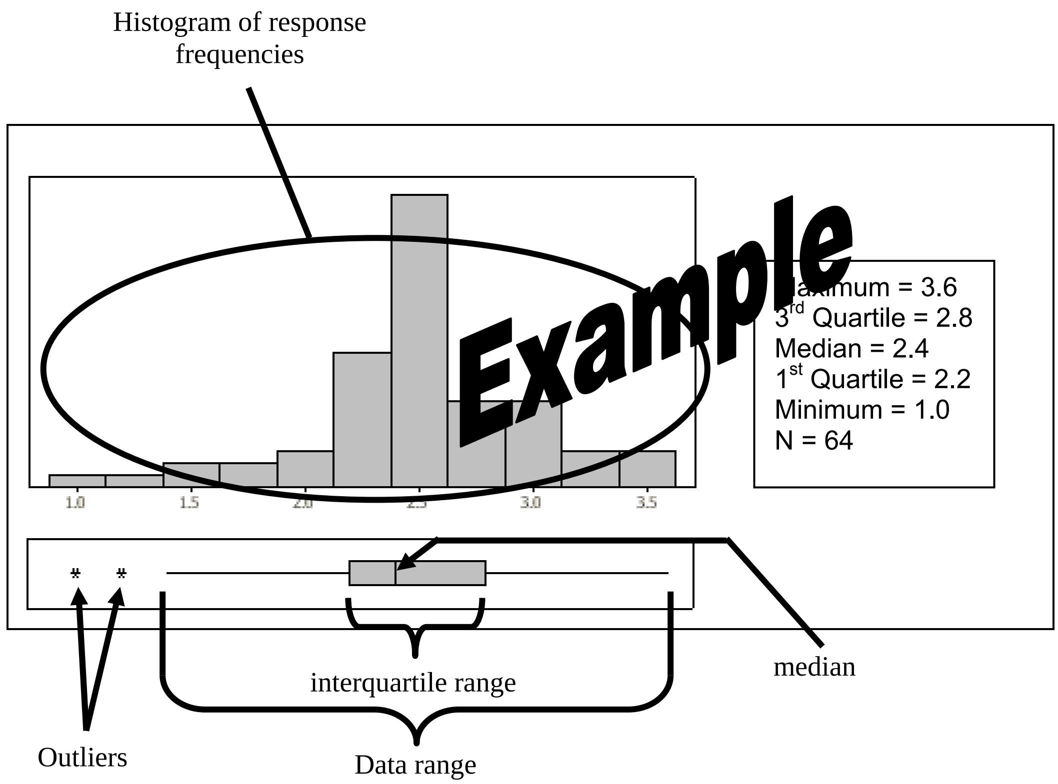


Figure 6: Example Distribution Graph for a Composite Score

The graphic on the bottom of Figure 6 is known as an outlier box plot. It visually shows the range and concentration of the full distribution of composite scores.

- The interquartile range is the space between the upper and lower quartiles, which also are known as the 75th and 25th quartiles, respectively. It contains 50% of all the cases.
- The solid lines extending from the box are called "whiskers." Their ends extend to the outer-most data points that are not outliers.
- Outliers are defined as data points that are greater than ±1.5 times the size of the interquartile range.
- Narrower interquartile boxes, shorter whiskers and the absence of outliers indicate more consistency among the scores. The opposite indicates more variability.

5.1.1 Project Challenge (*PC*)

The survey estimated the degree of challenge posed by the project through a combination of factors including:

- included life-cycle phases
- sources of technical challenge
- inter-organizational complexity
- contract duration
- contract stability (number of change orders)
- change in contract duration
- life-cycle phases currently in execution
- total project effort
- contract value
- requirements' completeness and stability
- percent change of contract value
- dollar change of contract value

This information was collected through responses to questions *Proj01*, *Proj02*, *Proj08*, *Cont01* through *Cont07*, *Cont10* through *Cont12, and Cont14*.

ID	Question	Response range
Proj01	What phases of the integrated product life cycle are or will be included in this project?	Scored by the number of life-cycle phases included • concept refinement • technology dev't & demo • development • mf'g / production • verification / validation • training • deployment • operation • support • disposal

ID	Question	Response range
Proj02	What phase or phases of the integrated product life cycle is this project presently executing?	Scored by the number of life-cycle phases in execution • concept refinement • technology dev't & demo • development • mf'g / production • verification / validation • training • deployment • operation • support • disposal
Proj08	The project is technically challenging because...	Scored by the number of challenges noted • no precedent • quality attribute constraints • large development effort • immature technology • extensive interoperability • insufficient resources • insufficient skills
Cont01	What is the current total contract value of this project?	• <$ 10 M • <$ 100M • <$ 1 B • <$ 10 B • >$ 10 B
Cont02	What is the current total planned duration of this project?	• <12 months • 12-24 months • 24-48 months • 48-96 months • 96-192 months • >192 months
Cont03	What was the initial contract value of this project?	• <$ 10 M • <$ 100M • <$ 1 B • <$ 10 B • >$ 10 B
Cont04	What was the initial total planned duration of this project?	• <12 months • 12-24 months • 24-48 months • 48-96 months • 96-192 months • >192 months
Cont05	How many contract change orders have been received?	• <= 1 • <=10 • <= 100 • <=1000 • > 1000
Cont06	Approximately how many person-years of effort are allocated to be spent on this project within your organization?	• < 10 • < 50 • < 200 • < 2000 • > 2000

ID	Question	Response range
Cont07	What program acquisition category (ACAT level) is your program classified at?	• Don't Know • ACAT IAC • ACAT IAM • ACAT IC • ACAT ID • ACAT II • ACAT III • Other
Cont10	How many stakeholders (including internal and external) are involved in this project?	Numeric entries for each of the following stakeholder categories • acquirers • SI contractors • maintenance contractors • dev't co-contractors • dev't sub-contractors • oversight contractors • users • others Entries were quantized as 1, 2, 3, or >3
Cont11	What percentage of the customer technical requirements were marked "To Be Determined" at time of contract award?	• <1% • 1-5% • 5-20% • >20%
Cont12	What percentage of the customer's technical requirements are currently marked "To Be Determined"?	• <1% • 1-5% • 5-20% • >20%
Cont14a	Approximately what percentage of non-recurring engineering (NRE) does systems engineering represent?	0 to 100% quantized as • 0 – 5% • 5 -5 10% • 10 – 15% • 15 – 25% • > 25%
Cont14b	Is the NRE percentage estimated, or is it a measured value?	• Estimated • Measured

Using the process described in Section 5, the responses to these questions were combined to create a measure of Project Challenge—***PC***. Distribution of ***PC*** is seen in Figure 7.

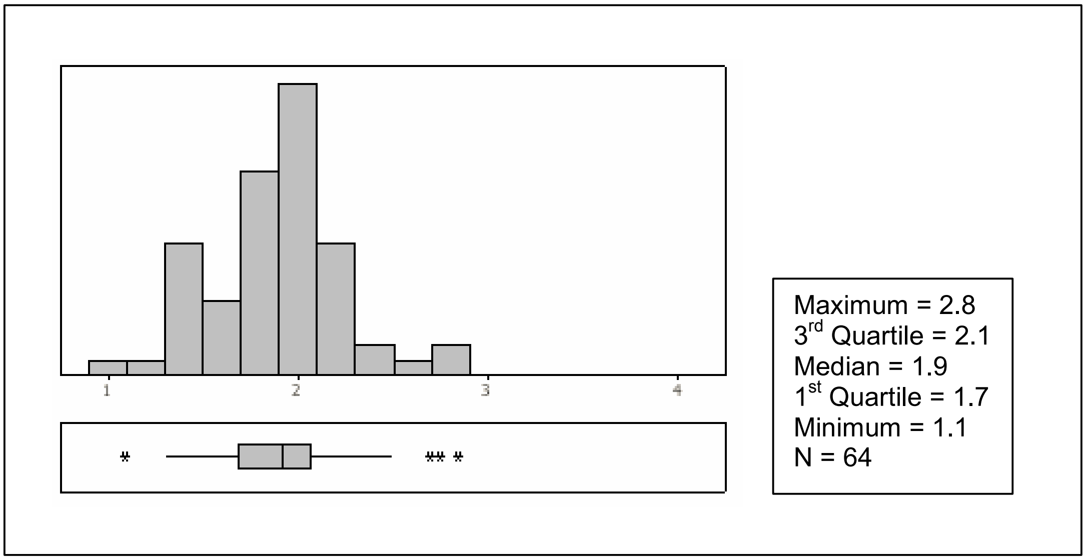


Figure 7: PC Composite Measure

This analysis reveals that the 64 projects responding to this survey were not unusually complex. On a complexity scale of 1 to 4 half of the projects ranged from 1.1 to 1.9, and the other half ranged from 1.9 to 2.8.

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.1.

5.1.2 Project Environment (*PE*)

Factors other than Project Challenge may also influence Project Performance. Factors considered in the survey included:

- the customer type
- the acquiring organization
- the end user
- the position in systems hierarchy
- the deployment environment
- the contract type
- the percent of effort subcontracted
- the development organizations CMMI-related capabilities
- the development organization’s process improvement efforts
- the development organization’s prior experience

This information was collected through responses to questions *Prod01* through *Prod05*, *Proj09*, *Cont08*, *Cont15*, *Org01* through *Org05*, and *Org07*. Response distributions are shown below.

As seen in Figure 8, the responding project's customers were primarily the government or the prime contractors; thus the respondent's projects were being executed either by the prime contractor or a second-tier subcontractor, with nearly 70% of the responses provided by the prime contractors.

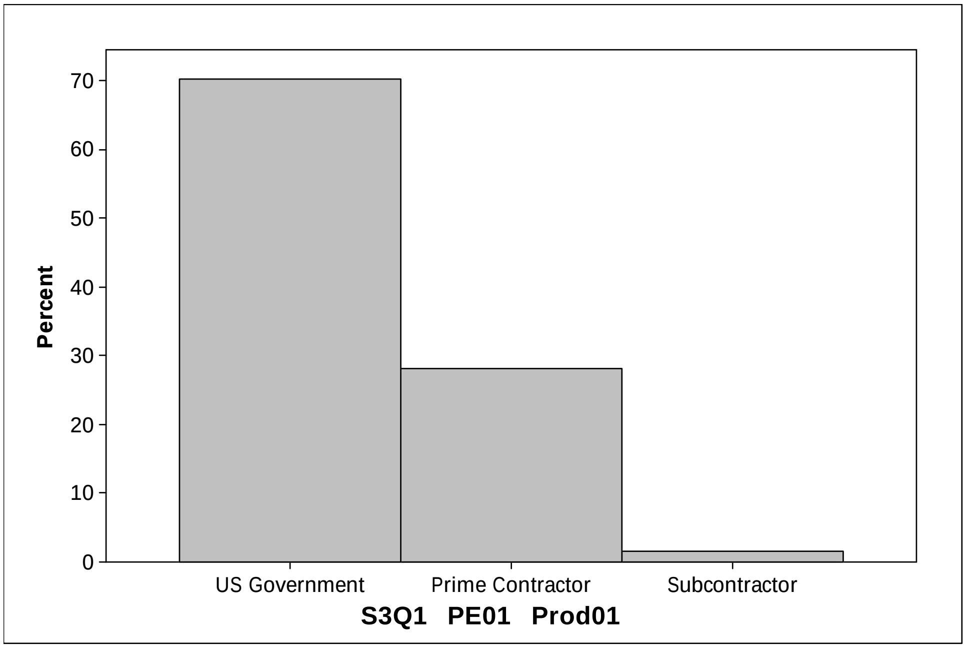


Figure 8: Prod01 – Which Selection Best Characterizes Your Customer?

The distribution of the acquiring organizations is seen in Figure 9. A large number of the acquirers are contained in the "Other" category. A review of the responses indicates that these acquirers are primarily foreign governments. The projects in the "Commercial" category are those that list the customer as a "Prime Contractor" or "Subcontractor" in Figure 8. The questionnaire collected no information to further identify those projects in the "Other Government" category.

Figure 10 shows the distribution of the project's end users; a distribution substantially similar to the acquirer distribution of Figure 9. Note that the bars on the graph sum to greater than 100%. This is due to the fact that some projects have more than one set of end-users

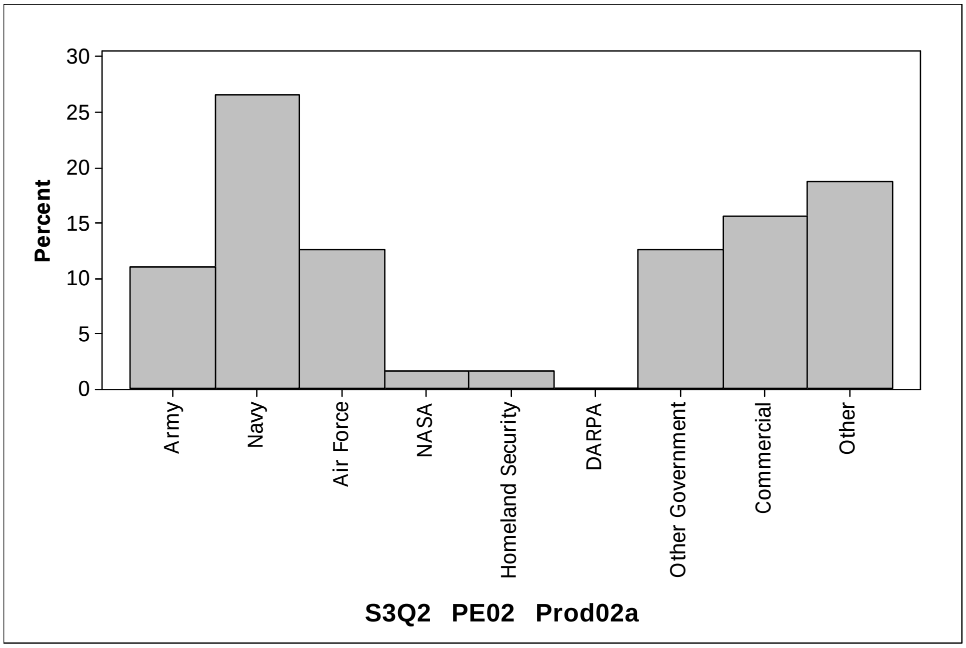


Figure 9: Prod02 - Who Is Acquiring This Product?

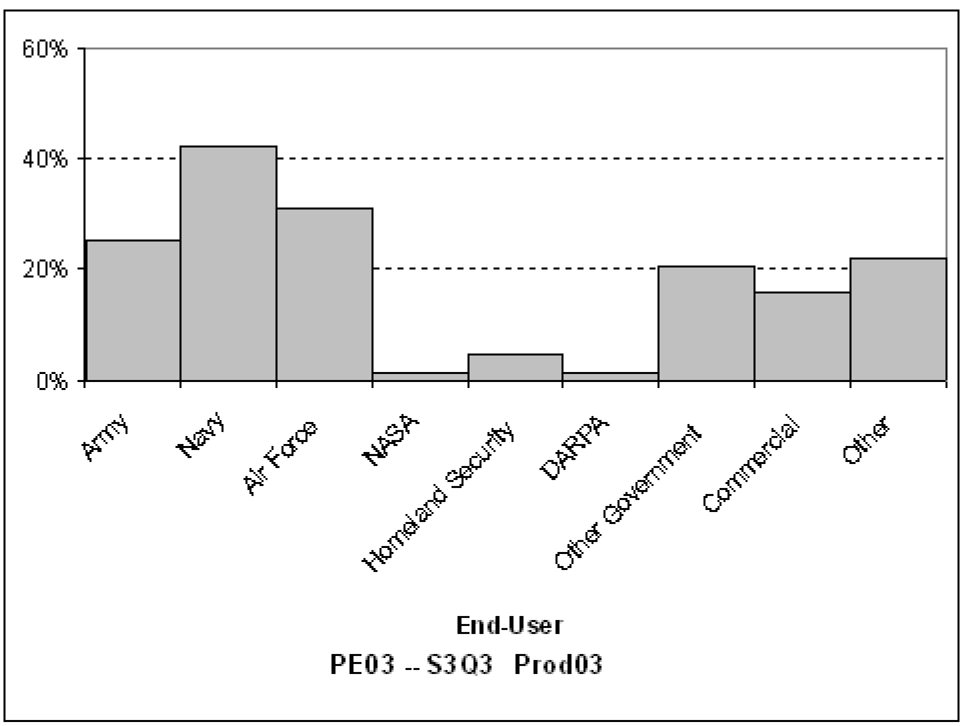


Figure 10: Prd03 - Who Is Primary End User (or Users) of This Product?

Figure 11 shows the position of the delivered product in a systems hierarchy divided into categories:

- system of systems
- system
- subsystem
- component
- process
- material
- other

While the definitions of these terms are somewhat nebulous, our intent was to try to characterize the projects in a manner that would enable us to identify the importance of Systems Engineering for each category. Unfortunately, the number of responses received was not sufficient to enable a meaningful analysis.

As seen in Figure 11, most of the respondents classify their products as a system. A smaller but not insignificant number consider their products to be systems-of-systems.

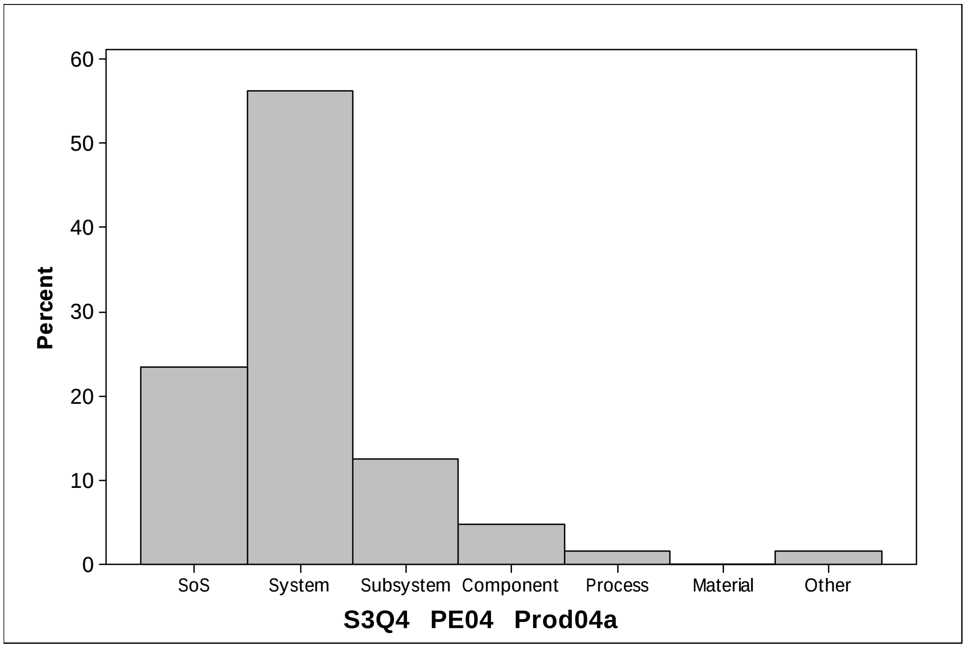


Figure 11: Prod04 - In the Context of the Ultimate Product Delivered to the End User, Where Does This Project Fit in the Following Hierarchy?

The distribution of the deployment environment is seen in Figure 12. The projects contained within the “Other” category were primarily deployed in combinations of the other environments.

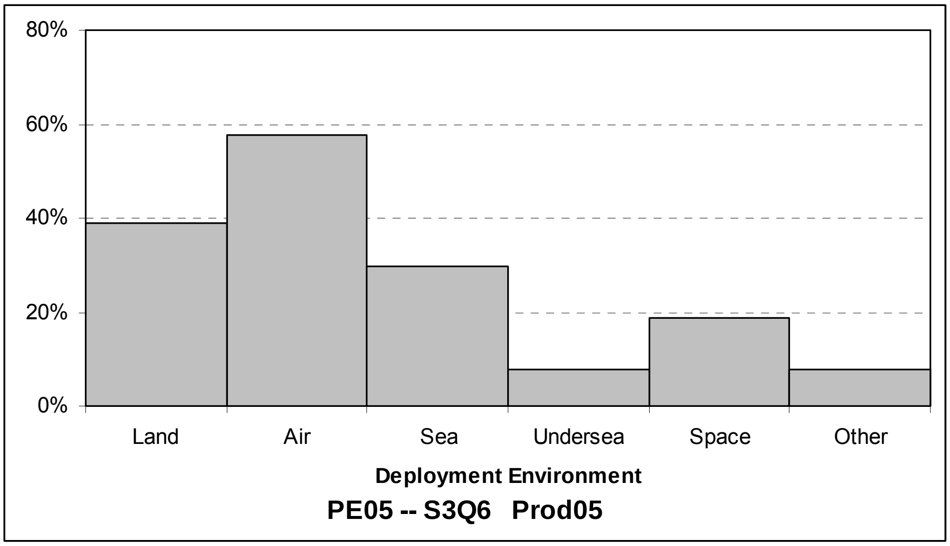


Figure 12: Prod05 –Where Will the System Resulting From This Project be Used?

Project execution will fall within a continuum ranging from

- The project is executed entirely by the prime contractor; to
- The project is entirely subcontracted to other suppliers.

Figure 13 shows the distribution of the responses. These responses were then binned in categories of 0 to 5%, 5 to 25%, 25 to 50%, and greater than 50%, as seen in Figure 14.

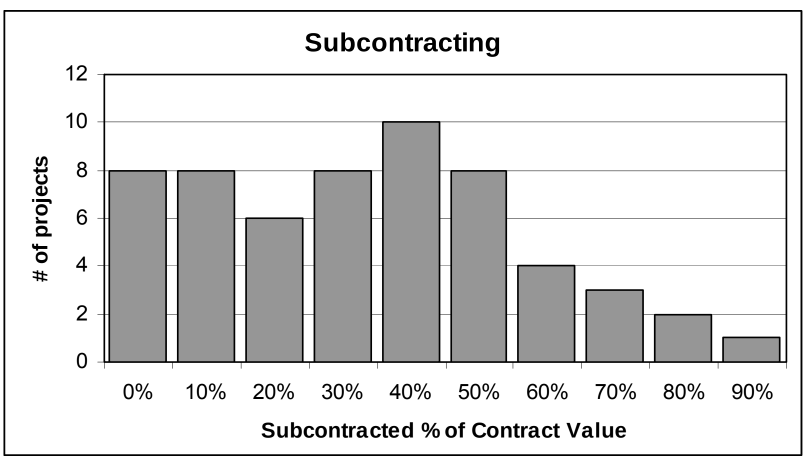


Figure 13: Distribution of Subcontracted Effort

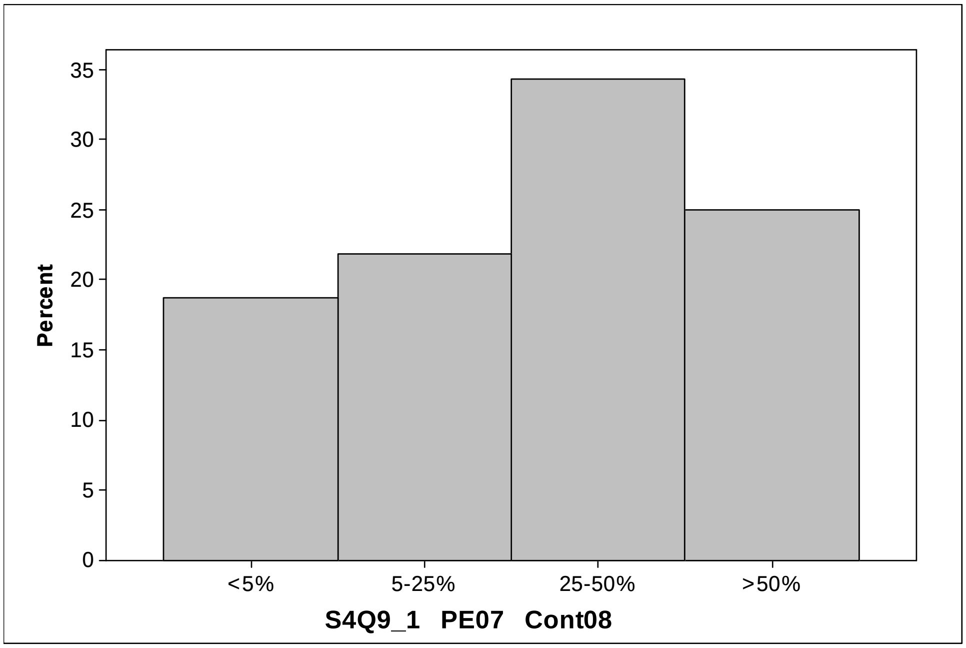


Figure 14: Cont08 - What Percentage of the Total Contract Value is Subcontracted to Your Suppliers?

Various contract types may be executed for a project; in fact, a project may actually include multiple contracts of different types. Respondents were asked which of the following types of contracts applied to their projects:

- FFP: Firm fixed price – FAR 16.202
- FP+EPA: Fixed price with economic price adjustment – FAR 16.203
- FP+PPR: Fixed price with prospective price redetermination – FAR 16.205
- FP+RPF: Fixed ceiling with retroactive price redetermination – FAR 16.206
- FFP, LOE: Firm fixed price, level of effort – FAR 16.207
- CR: Cost reimbursement – FAR 16.302
- CS: Cost sharing – FAR 16.303
- CPIF: Cost plus incentive fee – FAR 16.304
- CPFF: Cost plus fixed fee – FAR 16.306
- FPIF: Fixed price incentive – FAR 16.403
- FPAF: Fixed price with award fees – FAR 16.404
- CPAF: Cost plus award fee – FAR 16.405
- Other

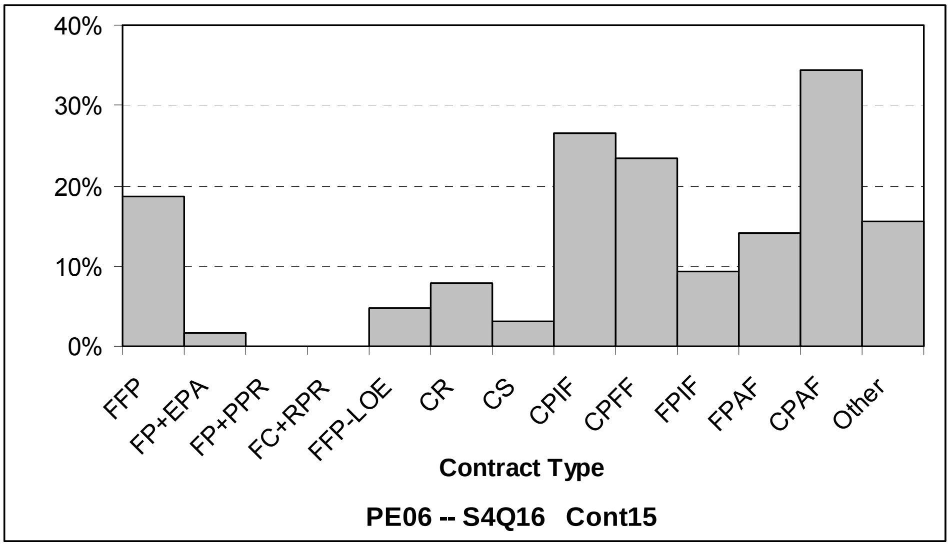


Figure 15: Cont15 - What Type of Contract(s) was Awarded for This Project?

As seen in Figure 15, contract types varied across the project sample with

- 19% being FFP: Firm fixed price -- FAR 16.202
- 2% being FP+EPA: Fixed price with economic price adjustment -- FAR 16.203
- 5% being FFP, LOE: Firm fixed price, level of effort -- FAR 16.207
- 8% being CR: Cost reimbursement -- FAR 16.302
- 3% being CS: Cost sharing -- FAR 16.303
- 27% being CPIF: Cost plus incentive fee -- FAR 16.304
- 23% being CPFF: Cost plus fixed fee -- FAR 16.306
- 9% being FPIF: Fixed price incentive -- FAR 16.403
- 14% being FPAF: Fixed price with award fees -- FAR 16.404
- 34%1 being CPAF: Cost plus award fee -- FAR 16.405
- 16% being Other

This analysis reveals that most of the contracts were some form of cost-reimbursable contract.

5.1.2.1 CMMI-Related Project Environmental Factors (*PE*$_{CMMI}$)

The responding project's capabilities related to CMMI varied across a wide range. Overall, CMMI-related capability was reported as moderate Capability in regards to CMMI was identified through questions *Org02*, *Org04*, *Org05*, and *Org06*.

ID	Question	Response range
Org02	To what extent do the tailored processes followed by this project comply with the organization's standard processes?	• highly compliant • largely compliant; • moderately compliant • not compliant

ID	Question	Response range
Org04	At what, if any, CMM or CMMI Maturity Level has this project's parent organization most recently been appraised?	• not appraised • ML1 • ML2 • ML3 • ML4 • ML5
Org05	When was the organization's most recent appraisal?	Entered dates quantized as: • <6 mo • <1 yr • < 2yr • >2yr
Org07	Has this project been objectively verified to be implementing processes consistent with a given CMM/CMMI maturity level?	• Not Appraised • ML1 • ML2 • ML3 • ML4 • ML5

Using the process described in Section 5, the responses to these questions were combined to create ***PE_{CMMI}***. Distribution of ***PE_{CMMI}*** is seen in Figure 16.

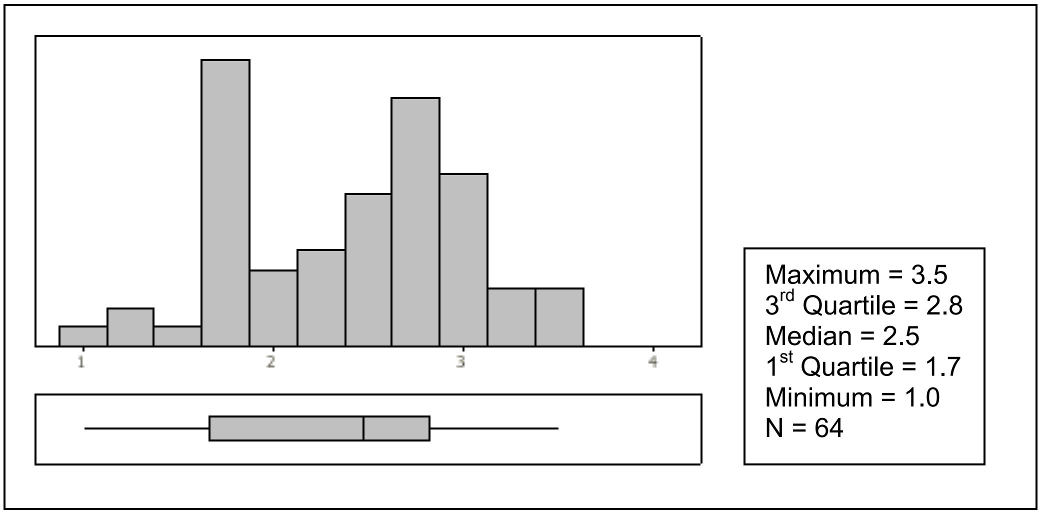


*Figure 16: CMMI-Related Capability (**PE_{CMMI}**) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.2.1.

Contextual information not included in the calculation of ***SEC_{CMMI}*** was collected by question *Org06*.

Org06 What model was used?
(1=CMMI-SE/SW/IPPD/SS, 2=CMMI-SE/SW/IPPD, 3=CMMI-SE/SW, 4=CMMI-SW)

5.1.2.2 Prior Experience Environmental Factors (***PE****EXP*)

The responding project indicated a moderate to high level of prior experience on similar projects. The prior experience of the project team and the organization was identified through questions *Proj09 and Org01a*.

ID	Question	Response range
Proj09	This project team has successfully completed projects similar to this in the past.	• strongly disagree • disagree • agree • strongly agree
Org01a	This organization has successfully completed projects similar to this one in the past.	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{PE_{EXP}}$. Distribution of $\boldsymbol{PE_{EXP}}$ is seen in Figure 17.

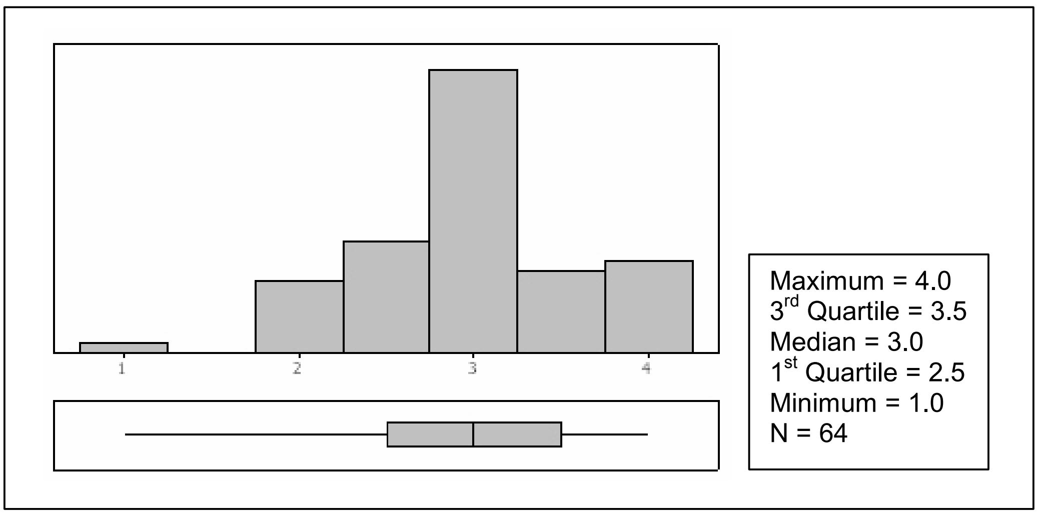


*Figure 17: Prior Experience (**PE**EXP) composite measure*

This analysis reveals that the respondent projects had relatively high levels of prior experience. On an experience scale ranging from 1 to 4, half of the projects ranged from 1 to 3, and the other half ranged from 3 to 4.

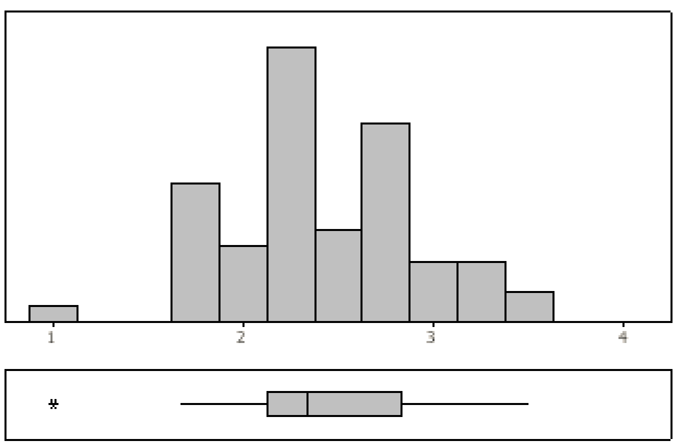
Distributions of the individual responses to these questions are found in APPENDIX D, Section D.2.2.

5.1.2.3 Process Improvement Environmental Factors (***PE****IMP*)

The responding projects indicated moderate Process Improvement capability. The Process Improvement capability of the project team and the organization was identified through questions *Org01b* and *Org03*.

ID	Question	Response range
Org01b	Process improvement efforts in this organization have been directly related to systems engineering.	• strongly disagree • disagree • agree • strongly agree
Org03	What process improvement activities have been undertaken on this project?	Scored by the number of process improvement methods utilized • ISO 9000 • Lean • Six Sigma • SE-CMM • SW-CMM • SECAM • EIA-731 • CMMI • none • other

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{PE_{IMP}}$. Distribution of $\boldsymbol{PE_{IMP}}$ is seen in Figure 18.



Maximum = 3.5
3rd Quartile = 2.8
Median = 2.3
1st Quartile = 2.1
Minimum = 1.0
N = 62

*Figure 18: Process Improvement (**PE_{IMP}**) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.2.3.

5.1.3 Systems Engineering Capability (*SEC*)

The survey collects data to assess projects' capabilities in each of the categories defined in Section 5. The responses to the survey questions within each category are analyzed to provide a measure of project capability within that category. This analysis is presented in the form of annotated distributions as shown in Figure 6.

5.1.3.1 Integrated Project Team Capability (SEC_{IPT})

The use of Integrated Project Teams by the reporting projects was moderate to high. The use of Integrated Project Teams was identified through questions *Proj03*, *Proj04*, *Proj06*, *Proj07a*, *Proj07b*

ID	Question	Response range
Proj03	This project uses integrated product teams (IPTs)	• Yes • No
Proj04	This project makes effective use of integrated product teams (IPTs)	• highly compliant • largely compliant; • moderately compliant • not compliant
Proj06	My suppliers actively participate in IPTs	• highly compliant • largely compliant; • moderately compliant • not compliant
Proj07a	This project has an IPT with assigned responsibility for systems engineering	• highly compliant • largely compliant; • moderately compliant • not compliant
Proj07b	This project has Systems Engineering representation on each IPT	• highly compliant • largely compliant; • moderately compliant • not compliant

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{IPT}}$. Distribution of SEC_{IPT} is seen in Figure 19.

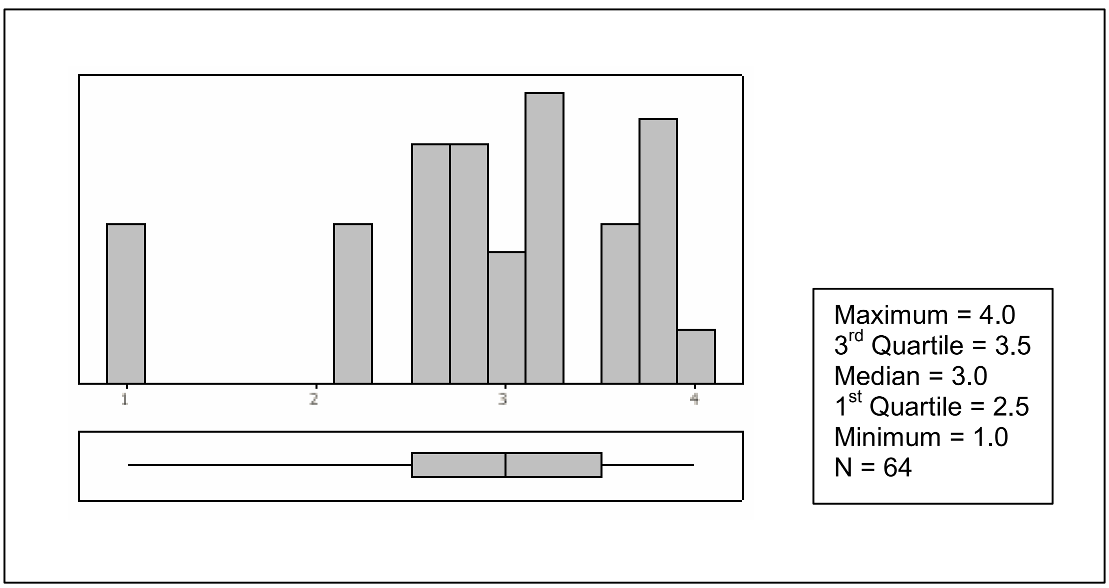


*Figure 19: Integrated Project Team Capability (**SEC_{IPT}**) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.1.

5.1.3.2 Project Planning Capability (SEC_{PP})

Projects reported moderate to high application of Project Planning best practices. Application of Project Planning best practices was identified through questions *PD01* through *PD09*

ID	Question	Response range
PD01	This project utilizes a documented set of systems engineering processes for the planning and execution of the project	• strongly disagree • disagree • agree • strongly agree
PD02a	This project has an accurate and up-to-date Work Breakdown Structure (WBS) that includes task descriptions and work package descriptions	• strongly disagree • disagree • agree • strongly agree
PD02b	This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is based upon the product structure	• strongly disagree • disagree • agree • strongly agree
PD02c	This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is developed with the active participation of those who perform the systems engineering activities	• strongly disagree • disagree • agree • strongly agree
PD02d	This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is developed with the active participation of all relevant stakeholders, e.g., developers, maintainers, testers, inspectors, etc.	• strongly disagree • disagree • agree • strongly agree
PD03a	This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is complete, accurate and up-to-date	• strongly disagree • disagree • agree • strongly agree
PD03b	This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is developed with the active participation of those who perform the systems engineering activities	• strongly disagree • disagree • agree • strongly agree
PD03c	This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is developed with the active participation of all appropriate functional stakeholders	• strongly disagree • disagree • agree • strongly agree
PD04a	This project has a top-level plan, such as an Integrated Master Plan (IMP), that is an event-driven plan (i.e., each accomplishment is tied to a key project event)	• strongly disagree • disagree • agree • strongly agree
PD04b	This project has a top-level plan, such as an Integrated Master Plan (IMP), that documents significant accomplishments with pass/fail criteria for both business and technical elements of the project	• strongly disagree • disagree • agree • strongly agree
PD04c	This project has a top-level plan, such as an Integrated Master Plan (IMP), that is consistent with the WBS	• strongly disagree • disagree • agree • strongly agree
PD05a	This project has an integrated event-based schedule that is structured as a networked, multi-layered schedule of project tasks required to complete the work effort	• strongly disagree • disagree • agree • strongly agree
PD05b	This project has an integrated event-based schedule that contains a compilation of key technical accomplishments (e.g., a Systems Engineering Master Schedule)	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response range
PD05c	This project has an integrated event-based schedule that references measurable criteria (usually contained in the Integrated Master Plan) required for successful completion of key technical accomplishments	• strongly disagree • disagree • agree • strongly agree
PD05d	This project has an integrated event-based schedule that is consistent with the WBS	• strongly disagree • disagree • agree • strongly agree
PD05e	This project has an integrated event-based schedule that identifies the critical path of the program schedule	• strongly disagree • disagree • agree • strongly agree
PD06	This project has a plan or plans for the performance of technical reviews with defined entry and exit criteria throughout the life cycle of the project	• strongly disagree • disagree • agree • strongly agree
PD07	This project has a plan or plans that include details of the management of the integrated technical effort across the project (e.g., a Systems Engineering Management Plan or a Systems Engineering Plan)	• strongly disagree • disagree • agree • strongly agree
PD08	Those who perform systems engineering activities actively participate in the development and updates of the project planning	• strongly disagree • disagree • agree • strongly agree
PD09	Those who perform systems engineering activities actively participate in tracking/reporting of task progress	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create SEC_{PP}. Distribution for the aggregate SEC_{PP} is shown in Figure 20.

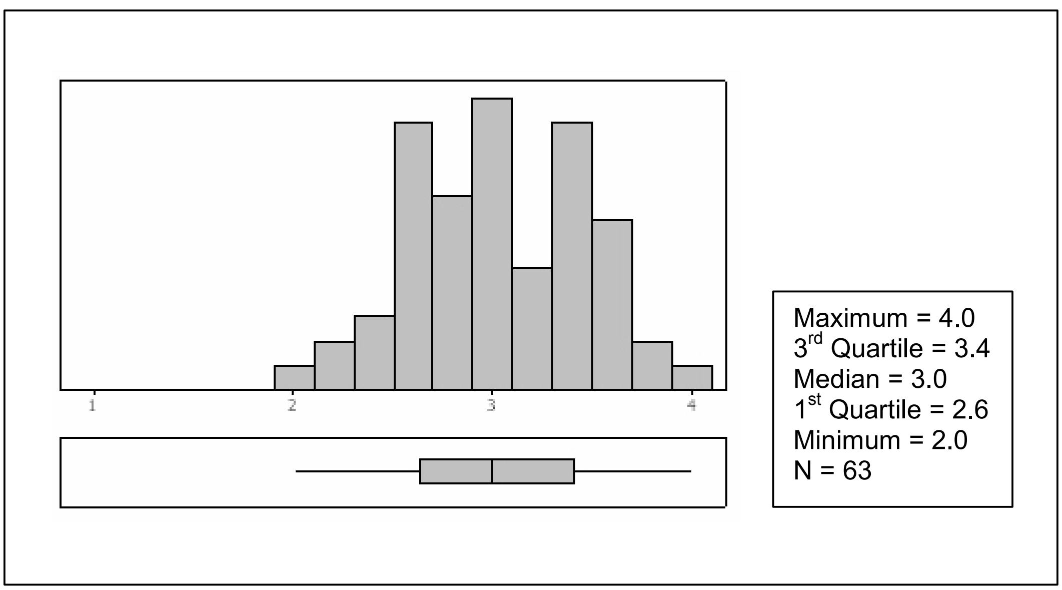


Figure 20: Project Planning Capability (SEC_{PP}) Composite Measure

This analysis shows a high level of Project Planning capability among the responding projects. On a Project Planning Capability scale of 1 to 4, no projects scored below 2.0. Half scored between 2.0 and 3.0. Half scored between 3.0 and 4.0.

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.2.

5.1.3.3 Project Monitoring and Control Capability (SEC$_{PMC}$)

The responding project's application of Project Monitoring and Control best practices varied over a wide range, with most projects reporting moderate to high deployment. Application of Project Monitoring and Control best practices was identified through questions *Cont13*, *Cont14b*, *Perf01*, *Perf02b*, *Perf02c*, *Perf02d*, *Perf02e*, *OPerf05*, *OPerf06*, *OPerf07*

<table>
<tr><th>ID</th><th>Question</th><th colspan="2">Response range</th></tr>
<tr><td>Cont13</td><td>Do you separately cost and track systems engineering activities?</td><td colspan="2">Yes
No</td></tr>
<tr><td>Cont14a</td><td>Approximately what percentage of non-recurring engineering (NRE) does systems engineering represent?</td><td colspan="2">Percentages quantized as:
• <= 5%
• <= 10%
• <= 15%
• <= 25%
• > 25%</td></tr>
<tr><td>Cont14b</td><td>Is the NRE percentage estimated, or is it a measured value?</td><td colspan="2">• estimated
• measured</td></tr>
<tr><td>Perf01</td><td>This project creates and manages cost and schedule baselines</td><td colspan="2">• strongly disagree
• disagree
• agree
• strongly agree</td></tr>
<tr><td>Perf02b</td><td>EVMS data are available to decision makers in a timely manner (i.e. current within 2 weeks)</td><td colspan="2">• strongly disagree
• disagree
• agree
• strongly agree</td></tr>
<tr><td>Perf02c</td><td>The requirement to track and report EVMS data is levied upon the project's suppliers</td><td colspan="2">• strongly disagree
• disagree
• agree
• strongly agree</td></tr>
<tr><td>Perf02d</td><td>Variance thresholds for CPI and SPI variance are defined, documented, and used to determine when corrective action is needed</td><td colspan="2">• strongly disagree
• disagree
• agree
• strongly agree</td></tr>
<tr><td>Perf02e</td><td>EVMS is linked to the technical effort through the WBS and the IMP/IMS</td><td colspan="2">• strongly disagree
• disagree
• agree
• strongly agree</td></tr>
<tr><td>OPerf05</td><td>Does this project track reports of problems from fielded items?</td><td>• Yes
• No</td><td rowspan="2">Scored by the number of posi-</td></tr>
<tr><td>OPerf06</td><td>Does the project conduct an engineering assessment of all field trouble reports?</td><td>• Yes
• No</td></tr>
</table>

ID	Question	Response range	
OPerf07	The results of this engineering assessment feed into …	• operational hazard risk assessments • materiel readiness assessments • system upgrades planning • other	tive responses

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{PMC}}$. Distribution of $\boldsymbol{SEC_{PMC}}$ is seen in Figure 21.

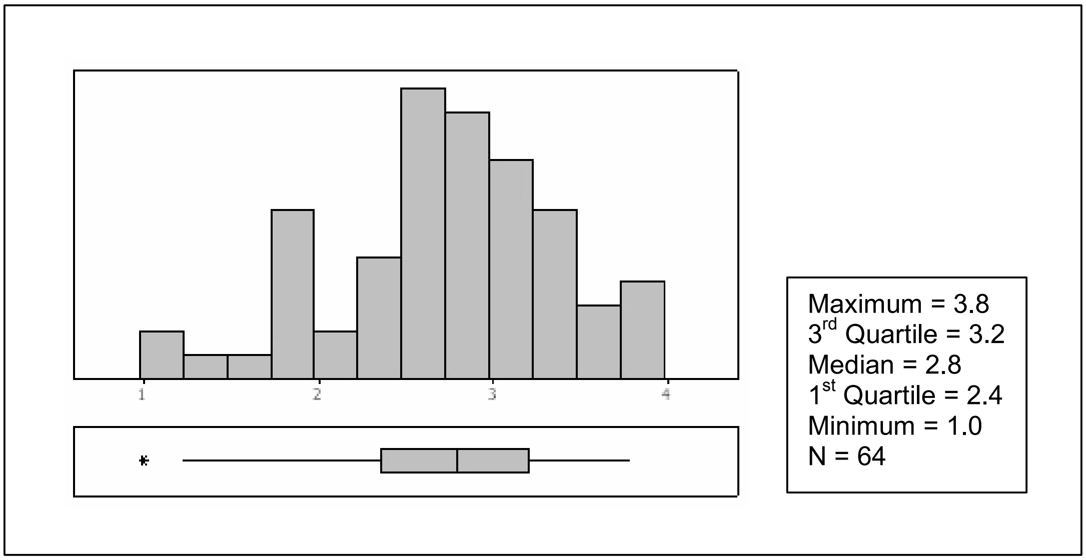


Figure 21: Project Monitoring and Control Capability ($\boldsymbol{SEC_{PMC}}$) Composite Measure

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.3.

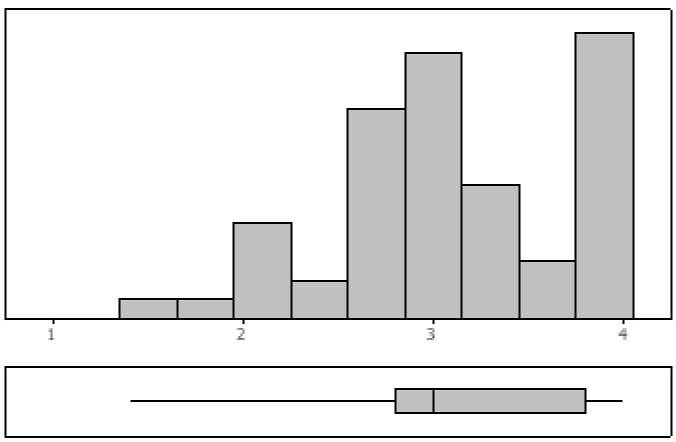
5.1.3.4 Risk Management Capability (SEC_{RSKM})

The responding projects reported moderate to high application of Risk Management best practices. Application of Risk Management best practices was identified through questions *PD11* and *PD12*.

ID	Question	Response range
PD11a	This project has a Risk Management process that creates and maintains an accurate and up-to-date list of risks affecting the project (e.g., risks to cost, risks to schedule, risks to performance)	• strongly disagree • disagree • agree • strongly agree
PD11b	This project has a Risk Management process that creates and maintains up-to-date documentation of risk mitigation plans and contingency plans for selected risks	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response range
PD11c	This project has a Risk Management process that monitors and reports the status of risk mitigation activities and resources	• strongly disagree • disagree • agree • strongly agree
PD11d	This project has a Risk Management process that assesses risk against achievement of an event-based schedule	• strongly disagree • disagree • agree • strongly agree
PD12	This project's Risk Management process is integrated with program decision-making	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{RSKM}}$. Distribution of $\boldsymbol{SEC_{RSKM}}$ is seen in Figure 22.



Maximum = 4.0
3rd Quartile = 3.8
Median = 3.0
1st Quartile = 2.8
Minimum = 1.4
N = 59

*Figure 22: Risk Management Capability (**SEC_{RSKM}**) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.4.

5.1.3.5 Requirements Development and Management Capability (SEC_{REQ})

The responding projects reported moderate to high application of Requirements Development and Management best practices. Application of Requirements Development and Requirements Management best practices were identified through questions *RD01* through *RD10*

ID	Question	Response range
RD01a	This project maintains an up-to-date and accurate listing of all requirements specified by the customer, to include regulatory, statutory, and certification requirements	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response range
RD01b	This project maintains an up-to-date and accurate listing of all requirements derived from those specified by the customer	• strongly disagree • disagree • agree • strongly agree
RD02	This project maintains up-to-date and accurate documentation clearly reflecting the hierarchical allocation of both customer and derived requirements to each element (subsystem, component, etc.) of the system in the configuration baselines	• strongly disagree • disagree • agree • strongly agree
RD03a	This project documents and maintains accurate and up-to-date descriptions of operational concepts and their associated scenarios	• strongly disagree • disagree • agree • strongly agree
RD03b	This project documents and maintains accurate and up-to-date descriptions of use cases (or their equivalent)	• strongly disagree • disagree • agree • strongly agree
RD03c	This project documents and maintains accurate and up-to-date descriptions of product installation, maintenance and support concepts	• strongly disagree • disagree • agree • strongly agree
RD04	This project has documented criteria for identifying authorized requirements providers to avoid requirements creep and volatility	• strongly disagree • disagree • agree • strongly agree
RD05	This project has documented criteria (e.g., cost impact, schedule impact, authorization of source, contract scope, requirement quality) for evaluation and acceptance of requirements	• strongly disagree • disagree • agree • strongly agree
RD06	The requirements for this project are approved in a formal and documented manner by relevant stakeholders	• strongly disagree • disagree • agree • strongly agree
RD07	This project performs and documents requirements impact assessments for proposed requirements changes	• strongly disagree • disagree • agree • strongly agree
RD08	This project develops and documents project requirements based upon stakeholder needs, expectations, and constraints	• strongly disagree • disagree • agree • strongly agree
RD09	This project has an accurate and up-to-date requirements tracking system	• strongly disagree • disagree • agree • strongly agree
RD10a	For this project, the requirements documents are managed under a configuration control process	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response range
RD10b	For this project, the requirements documents are accessible to all relevant project staff	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{REQ}}$. Distribution of $\boldsymbol{SEC_{REQ}}$ is seen in Figure 23.

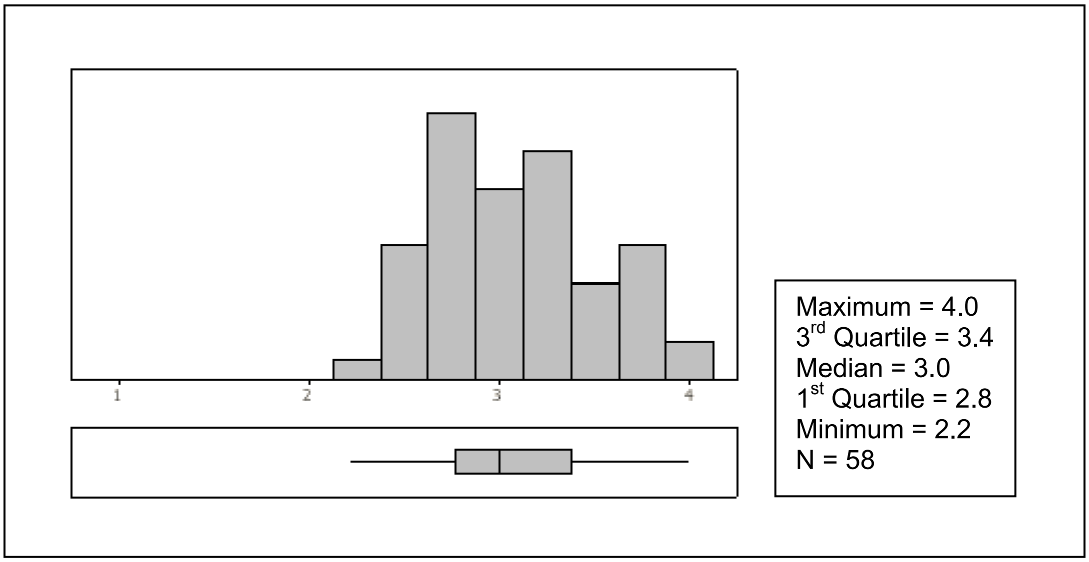


Figure 23: Requirements Development and Management Capability ($\boldsymbol{SEC_{REQ}}$) Composite Measure

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.5.

5.1.3.6 Trade Studies Capability (SEC_{TRADE})

The responding projects reported moderate to high application of Trade Studies best practices. Application of Trade Study best practices was identified through questions RD11 through RD13

ID	Question	Response range
RD11	Stakeholders impacted by trade studies are involved in the development and performance of those trade studies	• strongly disagree • disagree • agree • strongly agree
RD12	This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria	• strongly disagree • disagree • agree • strongly agree
RD13	Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{TRADE}}$. Distribution of $\boldsymbol{SEC_{TRADE}}$ is seen in Figure 24.

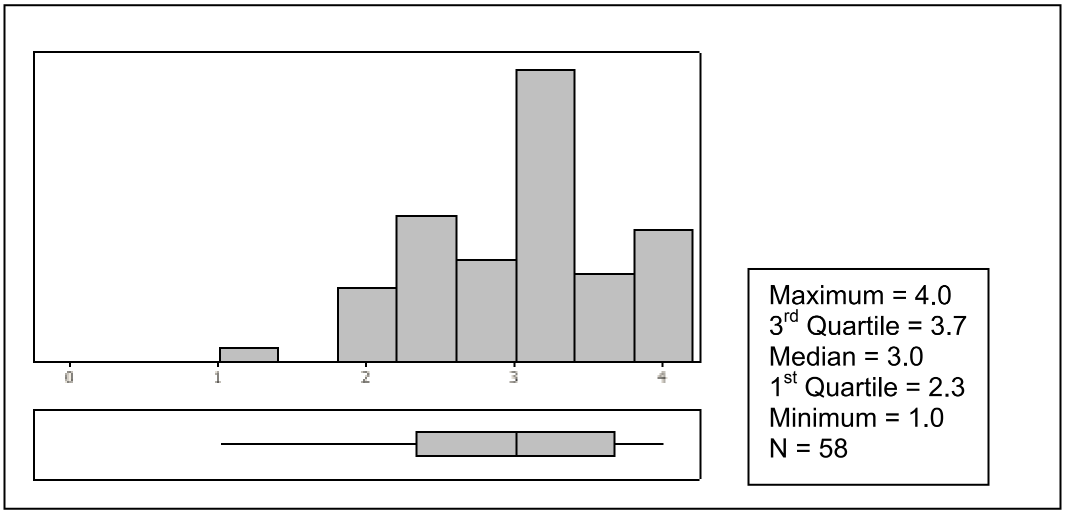


Figure 24: Trade Study Capability (SEC_{TRADE}) Composite Measure

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.6.

5.1.3.7 Architecture Capability (SEC_{ARCH})

The responding projects reported moderate to high application of Architecture best practices. Application of Architecture best practices was identified through questions *IF01* through *IF04.*

ID	Question	Response range
IF01	This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail	• strongly disagree • disagree • agree • strongly agree
IF02	Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them	• strongly disagree • disagree • agree • strongly agree
IF03a	For this project, the product high-level structure is documented, kept up to date, and managed under configuration control	• strongly disagree • disagree • agree • strongly agree
IF03b	For this project, the product high-level structure is documented using multiple views (e.g. functional views, module views, etc.	• strongly disagree • disagree • agree • strongly agree
IF03c	For this project, the product high-level structure is accessible to all relevant project personnel	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response range
IF04	This project has defined and documented guidelines for choosing COTS product components	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{ARCH}}$. Distribution of $\boldsymbol{SEC_{ARCH}}$ is seen in Figure 25.

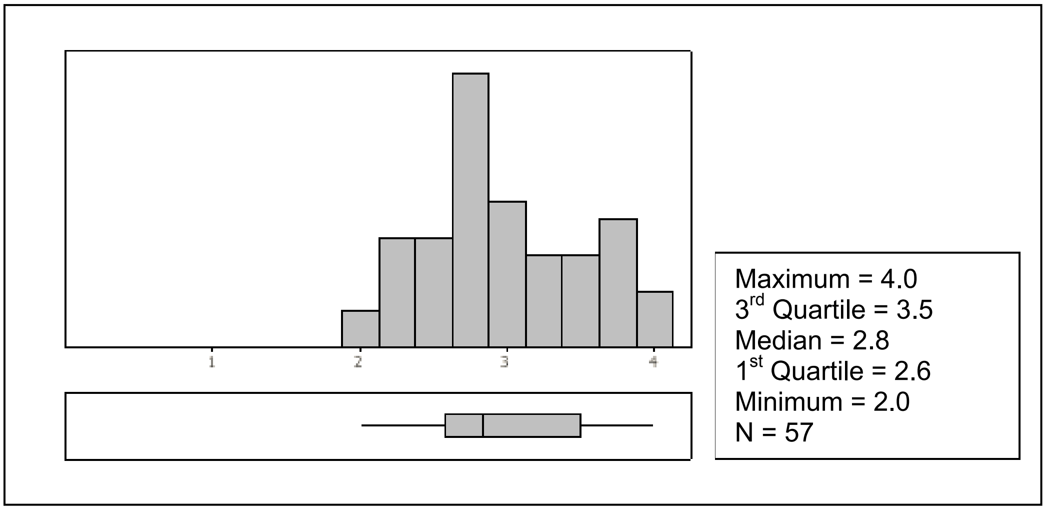


Figure 25: Product Architecture Capability ($\boldsymbol{SEC_{ARCH}}$) Composite Measure

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.7.

5.1.3.8 Technical Solution Capability (SEC_{TS})

The responding projects reported moderate to high application of Technical Solution best practices. Application of Technical Solution best practices was identified through questions *RD11* through *RD13* and *IF01* through *IF04*. $\boldsymbol{SEC_{TS}}$ *is actually an aggregate of Trade Study Capability (*$\boldsymbol{SEC_{TRADE}}$*) and Architecture Capability (*$\boldsymbol{SEC_{ARCH}}$*)*

ID	Question	Response Range
RD11	Stakeholders impacted by trade studies are involved in the development and performance of those trade studies	• strongly disagree • disagree • agree • strongly agree
RD12	This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria	• strongly disagree • disagree • agree • strongly agree
RD13	Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response Range
IF01	This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail	• strongly disagree • disagree • agree • strongly agree
IF02	Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them	• strongly disagree • disagree • agree • strongly agree
IF03a	For this project, the product high-level structure is documented, kept up to date, and managed under configuration control	• strongly disagree • disagree • agree • strongly agree
IF03b	For this project, the product high-level structure is documented using multiple views (e.g. functional views, module views, etc.)	• strongly disagree • disagree • agree • strongly agree
IF03c	For this project, the product high-level structure is accessible to all relevant project personnel	• strongly disagree • disagree • agree • strongly agree
IF04	This project has defined and documented guidelines for choosing COTS product components	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{TS}}$. Distribution of $\boldsymbol{SEC_{TS}}$ is seen in Figure 26.

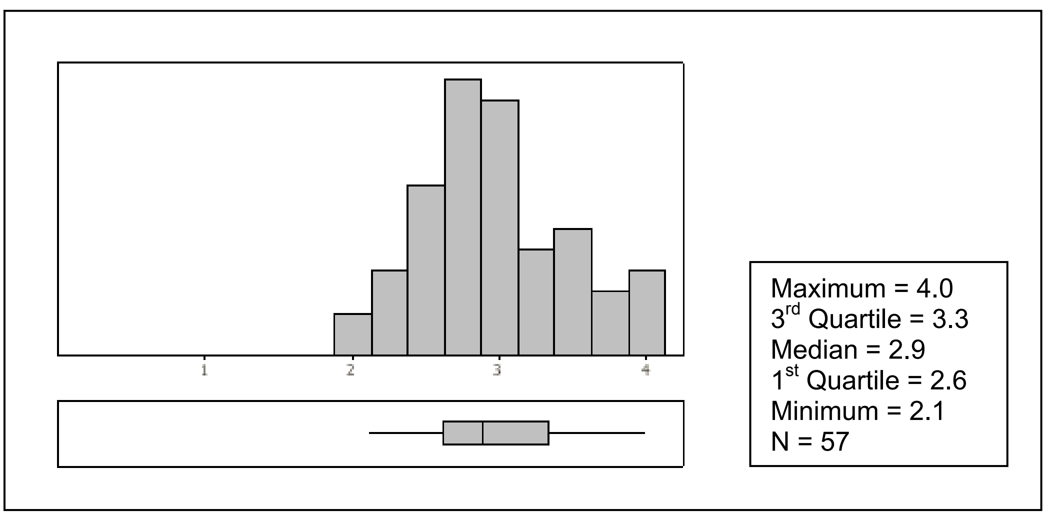


Figure 26: Technical Solution ($\boldsymbol{SEC_{TS}}$*) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.8.

5.1.3.9 Product Integration Capability (SEC_{PI})

The responding projects reported moderate to high application of Product Integration best practices. Application of Product Integration best practices was identified through question *IF05*.

ID	Question	Response range
IF05	This project has accurate and up-to-date documents defining its product integration process, plans, criteria, etc. throughout the life cycle	• strongly disagree • disagree • agree • strongly agree

After normalization, this response was used to calculate SEC_{PI}. Distribution of SEC_{PI} is seen in Figure 27.

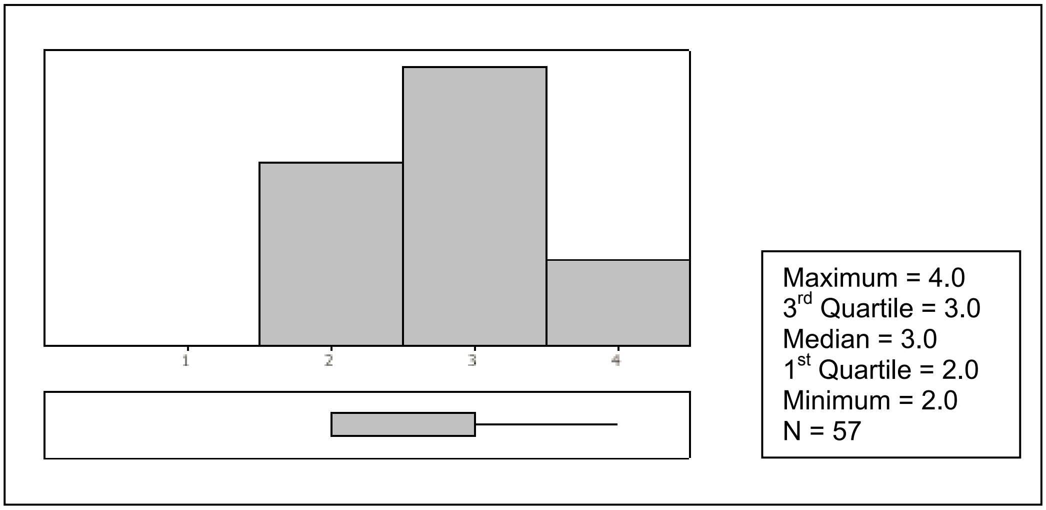


Figure 27: Product Integration Capability (SEC_{PI}) Measure

A distribution of the individual responses to this question is found in APPENDIX D, Section D.3.9.

5.1.3.10 Verification Capability (SEC_{VER})

The responding projects reported moderate to high application of Verification best practices. Application of Verification best practices was identified through questions V&V01 through V&V03.

ID	Question	Response range
V&V01a	This project has accurate and up-to-date documents defining the procedures used for the test and verification of systems and system elements	• strongly disagree • disagree • agree • strongly agree
V&V01b	This project has accurate and up-to-date documents defining acceptance criteria used for the verification of systems and system elements	• strongly disagree • disagree • agree • strongly agree

ID	Question	Response range
V&V02a	This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that defines entry and exit criteria for work products	• strongly disagree • disagree • agree • strongly agree
V&V02b	This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that includes training requirements for the reviewers	• strongly disagree • disagree • agree • strongly agree
V&V02e	This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that addresses identified risks and risk mitigation activities during reviews	• strongly disagree • disagree • agree • strongly agree
V&V02f	This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that examines completeness of configuration baselines	• strongly disagree • disagree • agree • strongly agree
V&V03	This project conducts non-advocate reviews (e.g. reviews by qualified personnel with no connection to or stake in the project) and documents results, issues, action items, risks, and risk mitigations	• strongly disagree • disagree • agree • strongly agree
V&V02c	This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that defines criteria for the selection of work products (e.g., requirements documents, test plans, system design documents, etc.) for review	• strongly disagree • disagree • agree • strongly agree
V&V02d	This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that tracks action items to closure	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{VER}}$. Distribution of $\boldsymbol{SEC_{VER}}$ is seen in Figure 28.

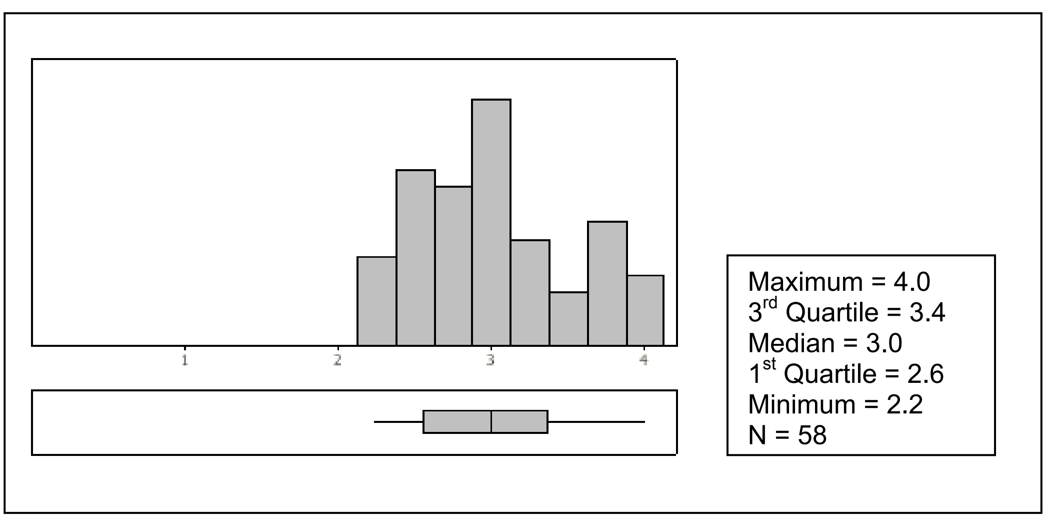


Figure 28: Verification Capability ($\boldsymbol{SEC_{VER}}$) Composite Measure

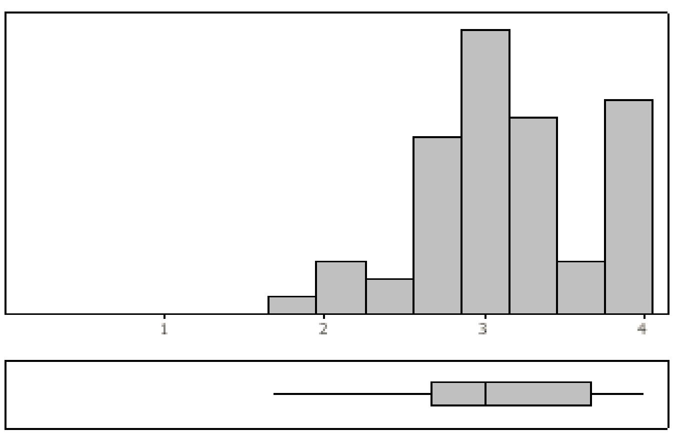
Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.10.

5.1.3.11 Validation Capability (SEC_{VAL})

The responding projects reported moderate to high application of Validation best practices. Application of Validation best practices was identified through questions *V&V04* and *V&V05*.

ID	Question	Response Rate
V&V04a	This project has accurate and up-to-date documents defining the procedures used for the validation of systems and system elements	• strongly disagree • disagree • agree • strongly agree
V&V04b	This project has accurate and up-to-date documents defining acceptance criteria used for the validation of systems and system elements	• strongly disagree • disagree • agree • strongly agree
V&V05	This project maintains a listing of items managed under configuration control	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create $\boldsymbol{SEC_{VAL}}$. Distribution of $\boldsymbol{SEC_{VAL}}$ is seen in Figure 29.



Maximum = 4.0
3rd Quartile = 3.7
Median = 3.0
1st Quartile = 2.7
Minimum = 1.7
N = 58

*Figure 29: Validation Capability (**SEC**$_{VAL}$) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.11.

5.1.3.12 Configuration Management Capability (SEC_{CM})

The responding projects reported high application of Configuration Management best practices. Application of Configuration Management best practices was identified through questions *V&V06* and *V&V07*.

ID	Question	Response Range
V&V06	This project has a configuration management system that charters a Change Control Board to disposition change requests	• strongly disagree • disagree • agree • strongly agree
V&V07	This project maintains records of requested and implemented changes to configuration-managed items	• strongly disagree • disagree • agree • strongly agree
V&V08	This project creates and manages configuration baselines (e.g., functional, allocated, product)	• strongly disagree • disagree • agree • strongly agree

Using the process described in Section 5, the responses to these questions were combined to create ***SEC$_{CM}$***. Distribution of ***SEC$_{CM}$*** is seen in Figure 30.

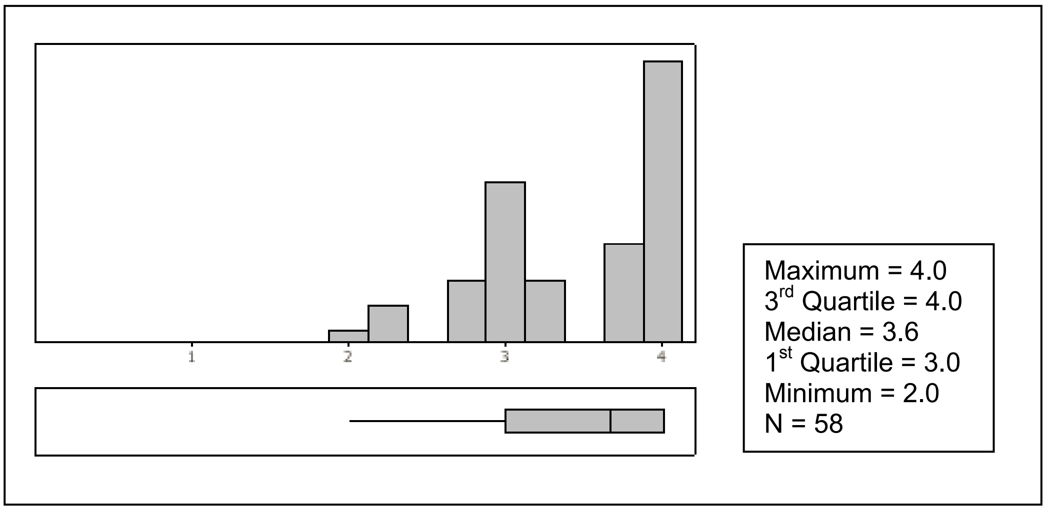


*Figure 30: Configuration Management Capability (**SEC$_{CM}$**) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.3.12.

5.1.3.13 Overall Systems Engineering Capability (*SEC*)

The capability subcategories of 5.1.3.1 through 5.1.3.12 may be combined to produce a measure of overall Systems Engineering Capability (***SEC***). After normalization, the results of each subcategory were linearly combined to create ***SEC.*** Distribution of ***SEC*** is seen in Figure 31. The responding projects reported moderate to high Systems Engineering Capability.

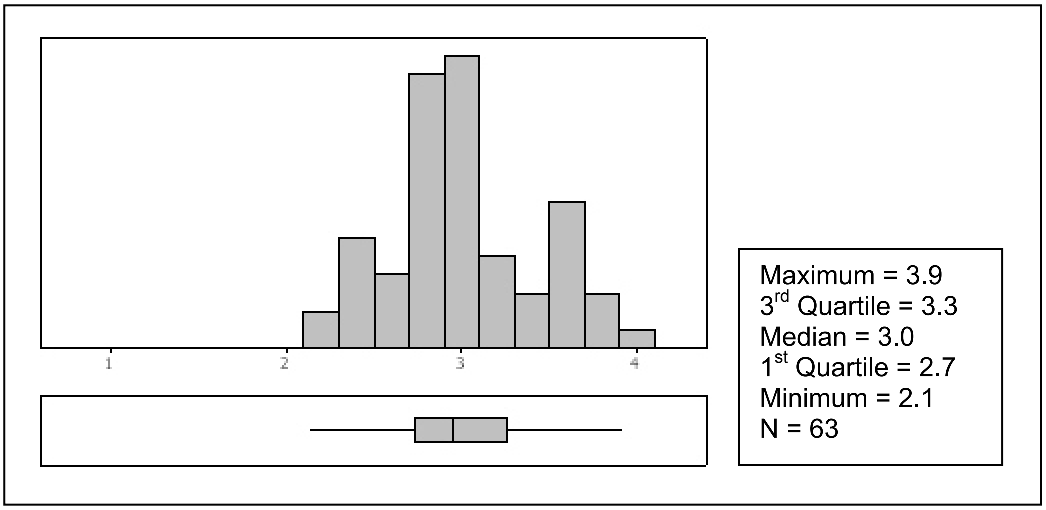


*Figure 31: Overall Systems Engineering Capability (**SEC)** Composite Measure*

5.1.4 Acquirer Capability (*AC*)

Because the survey respondents are the project suppliers, and not the project acquirers, any information gathered regarding the acquirers is second-hand information; that is, it is an evaluation of the acquirer from the perspective of the supplier. Nevertheless, there are a few parameters that can be measured to imply Acquirer Capability; parameters such as

- acquirer's participation on Integrated Project Teams (IPTs)
- acquirer's provision of a Systems Engineering Plan (SEP)
- quality of system requirements
- completeness of system requirements
- stability of system requirements

Although this survey was not specifically designed to assess the capabilities of the acquirers, these parameters can be combined to develop a rudimentary measure of Acquirer Capability (***AC***).

The responding projects reported moderate to high Acquirer Capability. The acquirer's capability was identified through questions *Proj05*, *Proj10a*, *Proj10b*, *PD10*, *Perf2a*, *Cont11*, and *Cont12*.

ID	Question	Response Range
Proj05	Both the supplier and the acquirer actively participate in IPTs	• Strongly Disagree • Disagree • Agree • Strongly Agree
Proj10a	The requirements for this project are well-defined	• Strongly Disagree • Disagree • Agree • Strongly Agree
Proj10b	The requirements for this project have not changed significantly throughout the life of the project to-date	• Strongly Disagree • Disagree • Agree • Strongly Agree

ID	Question	Response Range
PD10	The acquirer has provided this project with a Systems Engineering Plan	• Strongly Disagree • Disagree • Agree • Strongly Agree
Perf2a	Your customer requires that you supply EVMS data	• Strongly Disagree • Disagree • Agree • Strongly Agree
Cont11	What percentage of the customer technical requirements were marked “To Be Determined” at time of contract award?	• <1% • 1-5% • 5-20% • >20%
Cont12	What percentage of the customer’s technical requirements are currently marked “To Be Determined”?	• <1% • 1-5% • 5-20% • >20%

Using the process described in Section 5, the responses to these questions were combined to create ***AC***. Distribution of ***AC*** is seen in Figure 32.

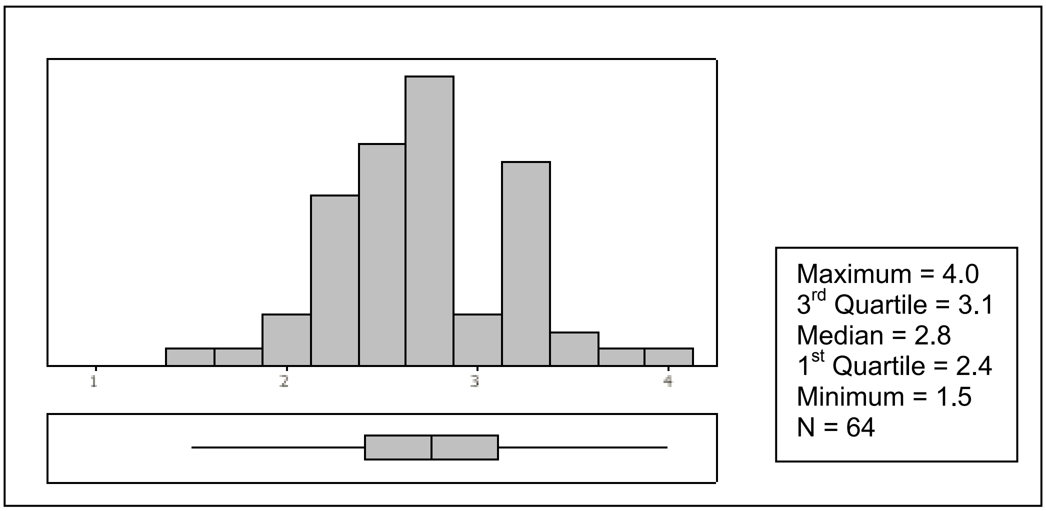


*Figure 32: Acquirer Capability (**AC**) Composite Measure*

Distributions of the individual responses to these questions are found in APPENDIX D, Section D.4.

5.1.5 Project Performance

As noted earlier, project cost, schedule, and scope are in opposition in a typical project. An attempt to improve one of these factors is often met with deterioration of the other two. In most cases, one of these factors is given priority over the other two. Some examples follow.

- For a project with strong financial constraints, meeting project cost goals may be a priority. This may necessitate schedule delays due to limits on resources. Scope reductions may also be applied to reduce the project effort.
- For a project with strong schedule constraints (e.g., a weapons system needed in the field NOW!), achieving delivery schedules may be a priority. This may necessitate additional costs

arising from more resources being applied to accelerate the program. Scope reductions may also be applied to eliminate or shorten project tasks.

- For a project with strong scope satisfaction constraints (e.g., a mission- or safety-critical system), achieving the specified scope may be a priority. This may necessitate additional costs arising from more resources being applied to achieve desired performance. Schedule slippage may occur as effort expands to address scope shortfalls.

The result is that Project Performance cannot be measured by cost compliance, schedule compliance, or scope compliance alone. All three must be considered.

5.1.5.1 Cost Performance ($Perf_C$)

The project's cost performance was identified through questions *Cont01*, *Cont03*, *Perf04a*, *Perf05a*, and *Perf06*.

ID	Question
Cont01	What is the current total contract value of this project?
Cont03	What was the initial contract value of this project?
Perf04a	What is the current estimated cost at completion for this project?
Perf05a	What is the projected cost variance at completion for the current contract baseline?
Perf06	What is the current cumulative (or final) EVMS Cost Performance Index (CPI) for this project?

Calculation of a measure of cost performance was somewhat more difficult than calculation of supplier capabilities as described in Section 5.1. The data upon which to form an evaluation included

- initial contract value (CV_I)
- current contract value (CV_C)
- current estimated cost-at-completion ($ECAC_C$)
- current estimated cost variance at completion ($EVAC_C$)
- EVMS cost performance index (CPI_C)

$ECAC_C$ and $EVAC_C$ were analyzed to identify the percent-cost variance of the project. CPI was separately evaluated. Projects were then graded on a scale of 1 to 4 as follows:

4 = under budget

3 = on budget (0 to 2% over budget)

2 = 2 to10% over budget

1 = >10% over budget

5.1.5.2 Schedule (duration) Performance ($Perf_D$)

The project's schedule (i.e., duration) performance was identified through questions *Cont02*, *Cont04*, *Perf04b*, *Perf05b*, *Perf07*, *OPerf03*, and *Operf04*

ID	Question	Response range
Cont02	What is the current total planned duration of this project?	

ID	Question	Response range
Cont04	What was the initial total planned duration of this project?	
Perf04b	What is the current estimated total duration for this project?	
Perf05b	What is the projected schedule variance at completion for the current contract baseline?	
Perf07	What is the current cumulative (or final) EVMS Schedule Performance Index (SPI) for this project?	
OPerf03	Overall, this project is performing per the schedule established in the current IMS approved by the acquirer	• strongly disagree • disagree • agree • strongly agree
Operf04	The schedule of this project's critical path, when compared to the current IMS approved by the acquirer is …	• >6 months late • 3-6 months late • 1-3 months late • within +/- 1 month • 1-3 months early • 3-6 months early • >6 months early

Calculation of a measure of schedule performance was similar to that for a measure of cost performance. The data upon which to form an evaluation included

- current total planned project duration (PD_C)
- initial total planned project duration (PD_I)
- current estimated total duration for this project (ED_C)
- projected schedule variance at completion for the current contract baseline (DV)
- current cumulative (or final) EVMS schedule performance index (SPI)
- EVMS update frequency
- current completion status of this project

ED_C and DV_C were analyzed to identify the percent-schedule variance of the project. SPI was separately evaluated. Projects were then graded on a scale of 1 to 4 as follows:

4 = early	3 = on schedule (0 to 2% late)
2 = 2 to 10% late	1 = >10% late

5.1.5.3 Scope Satisfaction Performance ($Perf_S$)

The project's scope performance was identified through question *OPerf02*

ID	Question	Response range
OPerf02	Requirements are being satisfied and remain on track to be satisfied in the product releases as originally planned; they are not being deleted or deferred to later releases	• strongly disagree • disagree • agree • strongly agree

5.1.5.4 Total Performance (*Perf*)

The measure ***Perf*** represents this total Project Performance and is calculated as the combination of $\boldsymbol{Perf_C}$, $\boldsymbol{Perf_D}$, and $\boldsymbol{Perf_S}$. Distribution of ***Perf*** is seen in Figure 33. The responding projects reported moderate to high Project Performance

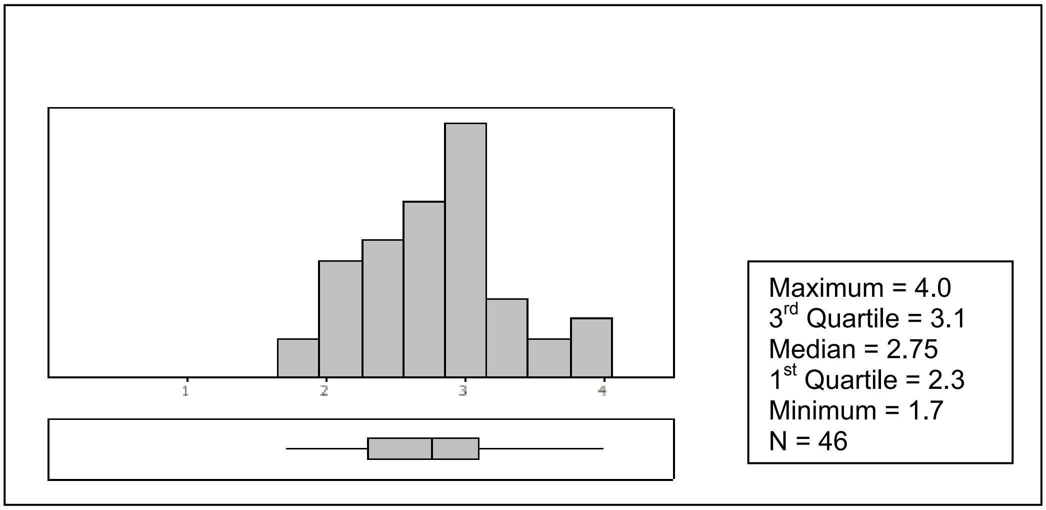


*Figure 33: Total Project Performance (**Perf**)*

For the purposes of the remaining analysis, the respondents were grouped into one of three categories:

- Best Performance — ***Perf*** > 3.0
- Moderate Performance — 2.5 ≤ ***Perf*** ≤ 3.0
- Lower Performance — ***Perf*** < 2.5

This trichotomy placed approximately equal numbers of respondents within each category.

We must stress the relative nature of these categories. These Project Performance categories do not range from worst possible performance score to the best possible performance score. Instead, they range from the lowest performance score achieved by any of projects in the survey sample to the highest performance score that was achieved.

5.2 RELATIONSHIPS BETWEEN *SEC*, *PC*, *PE*, *AC*, AND *PERF*

The objective of this survey is to identify relationships between Systems Engineering Capability and Project Performance. Given that our hypothesis is

$$\boldsymbol{Perf} = f(\boldsymbol{PC}, \boldsymbol{SEC}, \boldsymbol{AC}, \boldsymbol{PE})$$

We will accomplish this, by examining the following relationships:

- Project Performance (***Perf***) versus Systems Engineering Capability (***SEC***)

- Project Performance (***Perf***) versus Project Challenge (***PE***)
- Project Performance (***Perf***) versus Project Environment (***PE***)
- Project Performance (***Perf***) versus Acquirer Capability (***AC***)

We will also examine the relationship between Project Performance (***Perf***) and Systems Engineering Capability (***SEC***) as moderated by

- Project Challenge
- Project Environment
- Acquirer Capability

Relationships between driving factors (that is, Systems Engineering Capability subcategories ($\boldsymbol{SEC}_{XXX}$), Project Environment Factors, Project Challenge) and Performance (***Perf***) are illustrated using a mosaic graph. The mosaic graph provides an intuitive means of examining the statistical relationship between a dependent variable (Project Performance, depicted on the vertical axis) and an independent variable (such as a Systems Engineering Capability, depicted on the horizontal axis).

As an example, Figure 34 shows an illustration of the relationship between two survey variables: Project Planning capability and Project Performance. As noted in Section 5.1.3.2, the responses to a number of survey questions are processed to obtain a quantitative assessment of the supplier's Project Planning capabilities. Similarly, in Section 5.1.4, other questions are processed to obtain a quantitative assessment of the supplier's overall performance on the project. In constructing this graphic, we first establish thresholds that enable us to define three levels of Project Planning capability

- higher Project Planning capability
- moderate Project Planning capability
- lower Project Planning capability

The distribution of survey responses within these categories is one of the criteria used in establishing these thresholds. We then partition the data set, binning the survey responses per the thresholds.

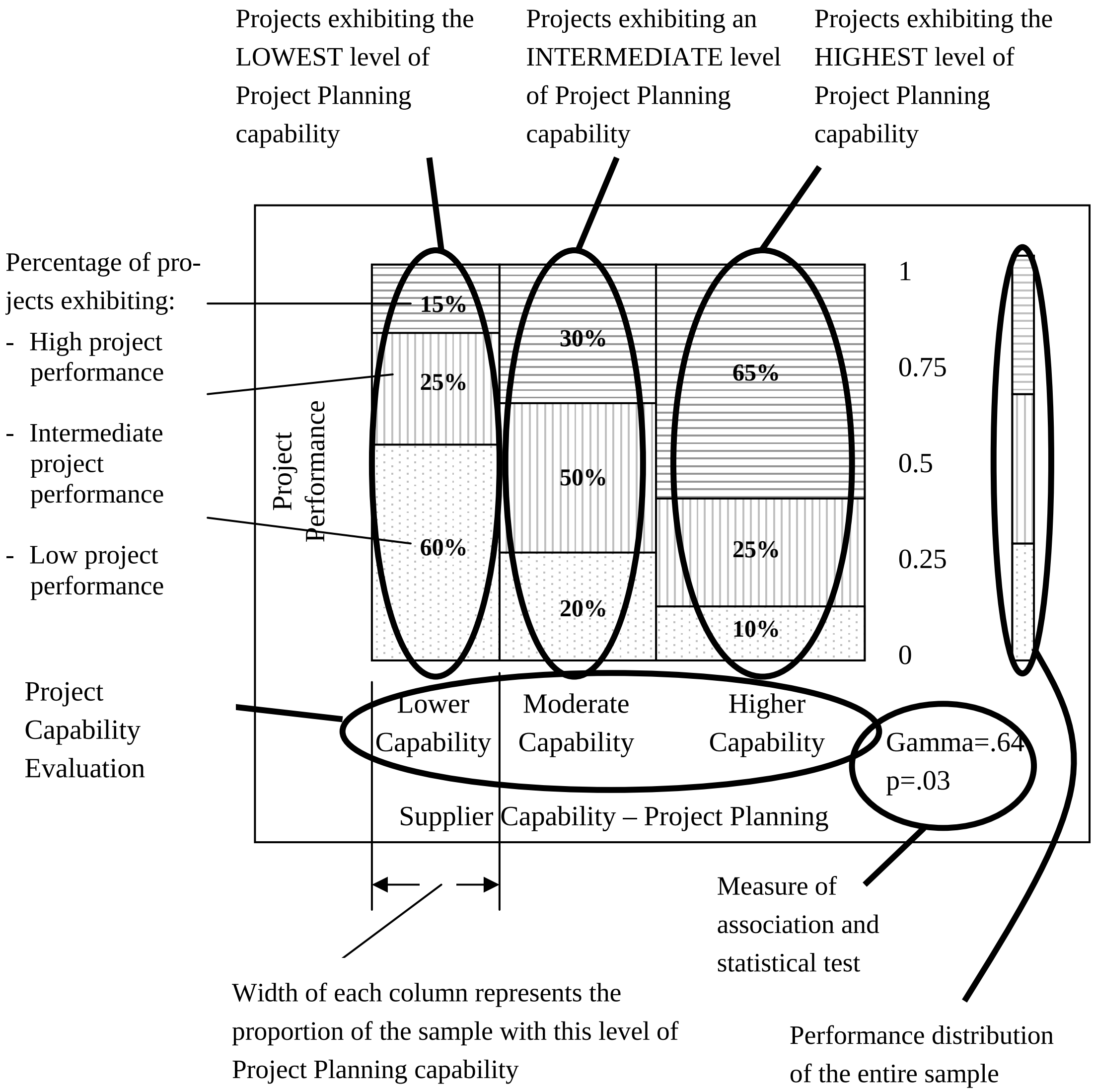


Figure 34: Mosaic Chart Key

Likewise, we establish thresholds that enable us to define three levels of Project Performance:

- high Project Performance
- intermediate Project Performance
- low Project Performance

For each of the Project Planning capability bins, we can then illustrate the distribution of Project Performance as a stacked column graph.

The mosaic graph provides additional information found in the width of each of its columns. This width is proportional to the quantity of responses within that bin. Finally, the column graph on the right shows the distribution of Project Performance responses for the entire sample (that is, for all Project Planning bins combined).

A measure of association and statistical test are also included.

- ***Gamma*** is a measure of association that expresses the strength of relationship between two ordinal variables. A clear, simple description of Goodman and Kruskal's *gamma* may be found in Linton Freeman's *Elementary Applied Statistics* [Freeman 1965]. Values of *gamma* are based on the difference between concordant (P) and discordant (Q) paired comparisons of the two variables. It is computed as (P-Q)/(P+Q), i.e., the excess of concordant pairs as a percentage of all pairs ignoring ties. Similar to Pearson's product moment relationship coefficient (*r*), *gamma* varies from +1 to -1, with
  - values near -1 indicating a strong opposing relationship
  - values near 0 indicating a weak or no relationship (statistical independence)
  - values near +1 indicating a strong supporting relationship

  Gamma is a Proportional Reduction in Error (PRE) statistic, so understanding its value is intuitively straightforward. Conceptually similar to Pearson's r^2 for interval or ratio data, a *gamma* value can be interpreted as the proportion of paired comparisons where knowing the rank order of one variable allows one to predict accurately the rank order of the other variable.

  Notionally, *gamma* values of less than 0.2 may be considered as weak, and values around 0.3 can be thought of as moderately strong. *Gamma* values in the neighborhood of 0.5 can be characterized as strong, while values over 0.6 are quite high for categoric survey data such as those in this report.

- **"p"** is generally interpreted as the probability that one would observe a statistical relationship in a sample of data by chance alone. By convention, values of $p < 0.05$ or $p < 0.01$ typically are used as a basis for rejecting the null hypothesis, i.e., having confidence that the relationship is not specious.

  Because of the small number of cases in the present survey, the *p* values for some of the weaker relationships are greater than 0.05. However, the percentage differences and related *gamma* values themselves are more meaningful for understanding the results than are the *p* values *per se*.

  Given the way in which the sample was drawn, we cannot generalize our univariate findings to the larger population of DoD programs; however, there is sufficient variation to analyze the relationships among the variables. It is those relationships that allow us to address the validity of assertions about the effects on program performance of Systems Engineering activities under varying circumstances.

With this understanding, interpretation of the mosaic graph is straightforward. Figure 34 tells us:

- Approximately 25% (estimated from the width of the first column) of the survey respondents exhibit low Project Planning Capability on their projects. Within this group:
  - 60% of the projects show low Project Performance
  - 25% of the projects show intermediate Project Performance, and
  - 15% of the projects show high Project Performance

- Approximately 35% (estimated from the width of the second column) of the survey respondents exhibit intermediate Project Planning Capability on their projects. Within this group:
  - 20% of the projects show low Project Performance
  - 50% of the projects show intermediate Project Performance, and
  - 30% of the projects show high Project Performance
- Approximately 40% (estimated from the width of the third column) of the survey respondents exhibit high Project Planning Capability on their projects. Within this group:
  - 10% of the projects show low Project Performance
  - 25% of the projects show intermediate Project Performance, and
  - 65% of the projects show high Project Performance
- *Gamma* = 0.64 describes the strong supporting relationship between Project Planning capability and Project Performance, while $p = 0.03$ indicates that the likelihood of a relationship of this magnitude happening by chance alone is only 3%.

Clearly, in this hypothetical case, better Project Planning capability is related to better Project Performance.

Note that the choice of bins is not necessarily limited to three. In principle, the data could be partitioned into two, four, or any number of bins. We use three categories in this Special Report because the relatively small number of projects that participated in the survey limits the confidence that one can have in the differences among categories. The number of comparisons cannot meaningfully approach the number of cases.

It should be stressed that, unlike the distribution graphs presented in Section 5.1, the mosaic charts describe relative rather than absolute differences. The Project Performance categories on the vertical axis do not range from worst possible performance score to the best possible performance score. Instead, they range from the lowest performance score achieved by any of projects in the survey sample to the highest performance score that was achieved. Thus, on an absolute scale of 1 (worst possible performance) to 4 (best possible performance), if all of the respondent's had indicated that their projects were performing relatively well and fell into the range from 2 to 4, the mosaic graph might consider those scoring from 2 to 2.7 as "Lower Performance," those scoring from 2.8 to 3.2 as "Moderate Performance," and those scoring from 3.3 to 4 as "Best Performance". The same is true for the Capability measure of the horizontal axis. It again is relative in nature, ranging from the lowest capability reported to the highest.

The relationships discussed throughout Section 5.2 are also summarized in Table 7, found in Section 7.

5.2.1 Relationships between Project Challenge (*PC*) and Project Performance (*Perf)*

Project Challenge may have a significant impact upon Project Performance. As expected the Project Challenge measure described in Section 5.1.1 showed a moderately strong negative statistical relationship with the Project Performance measure defined in Section 5.1.5.4, as shown in Figure 35.

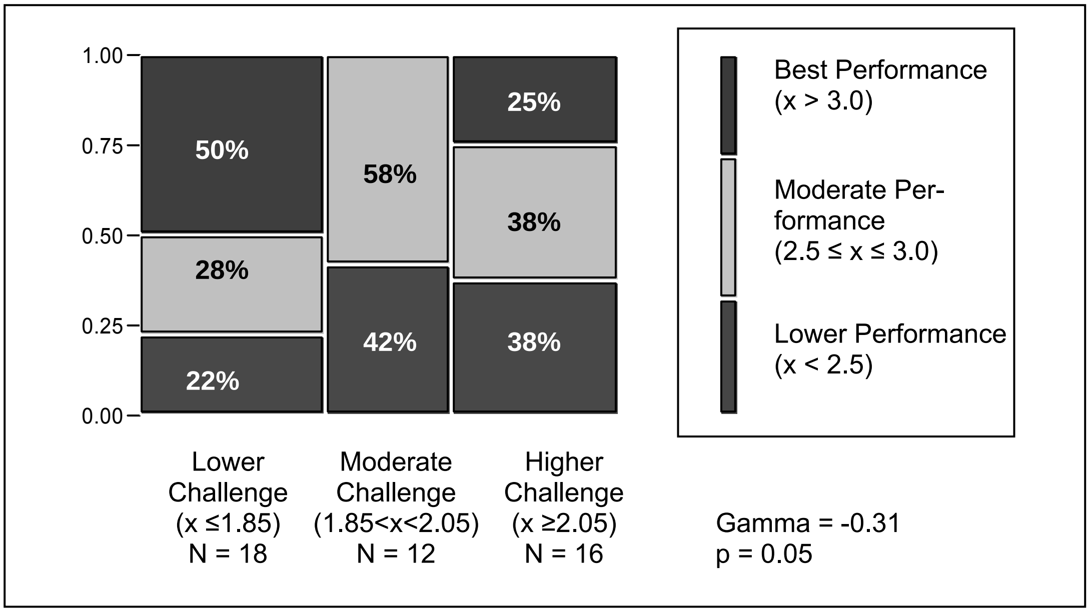


Figure 35: Relationship Between Project Challenge and Performance (***Perf*** *Versus* ***PC*** *)*

Project Challenge varied across the project sample with 18 projects having Lower Project Challenge, 12 having a Moderate Project Challenge, and 16 having Higher Project Challenge. Fifty percent of the projects with Lower Project Challenge exhibited Best Performance, while only 25% of the projects with Higher Project Challenge exhibited Best Performance. Similarly, although less consistent over the range of Project Challenge, only 22% of projects with Lower Project Challenge exhibited Lower Performance, while only 38% of projects with Higher Project Challenge exhibited Lower Performance.

A *Gamma* value of -0.31 confirms that there is a moderately strong negative relationship between Project Performance and the elements of Process Challenge addressed in this survey; i.e., performance degrades as the projects become more difficult. A *p* value of 0.05 indicates that there is a 5% probability that this type of relationship could spontaneously occur by chance alone.

5.2.2 Relationships between Project Environment (*PE*) and Project Performance (*Perf*)

Factors other than Systems Engineering Capability may impact Project Performance. To identify these impacts, we will examine the following relationships:

Customer category versus Performance	(	***Prod01***	versus	***Perf***	)
Acquiring organization versus Performance	(	***Prod02***	versus	***Perf***	)
Position in Systems Hierarchy versus Performance	(	***Prod04***	versus	***Perf***	)
Subcontracted percentage versus Performance	(	***Cont08***	versus	***Perf***	)
Systems Engineering Content versus Performance	(	***Cont14a***	versus	***Perf***	)
CMMI-based process management versus Performance	(	$\boldsymbol{SEC_{CMMI}}$	versus	***Perf***	)
Prior Experience versus Performance	(	$\boldsymbol{SEC_{EXP}}$	versus	***Perf***	)
Process Improvement versus Performance	(	$\boldsymbol{SEC_{IMP}}$	versus	***Perf***	)

Most of the Project Environment (*PE*) measures in the relationships with Project Performance (*Perf)* that follow are not easily amenable to sound summary statistical analysis. There either are

not enough projects in each of the possible response categories or the range of answers the projects gave cannot be classified evenly enough into homogeneous categories. Some pertinent percentage differences do exist. However, the summary relationships remain obscure. Hence, we have refrained from presenting Gamma measures of association and statistical tests in this section.

In question *Prod01*, customers were categorized as Government, Prime Contractor, or Subcontractor, as noted in Section 5.1.2.

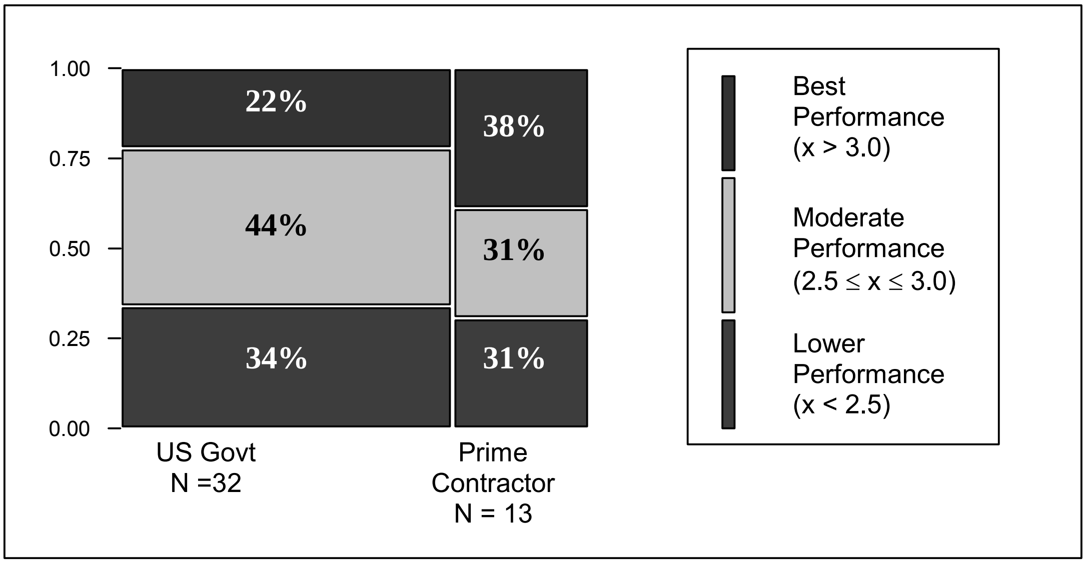


Figure 36: Relationship Between Customer Category and Performance (***Perf*** *Versus* ***Prod01*** *)*

As shown in Figure 36, there was some variation based upon the customer to whom the product was delivered. U.S. government organizations were the customer for 32 projects (i.e., the project was being executed by the Prime Contractor). Of these projects, only 22% exhibited Best Performance. The Prime Contractor was the customer for 13 projects (i.e., the project was being executed by a first-tier subcontractor). Of these projects, the percentage exhibiting Best Performance increased to 38%. Projects where the customer was a subcontractor (i.e., where the project was being executed by a lower tier contractor), are not shown here. The number of projects in this category was insufficient for meaningful analysis and too small to honor our promise of non-disclosure made to the survey participants.

Various hypotheses explaining this result could be made. In general, one would expect the Prime Contractor's projects to be larger and more complex than the Subcontractor's projects. This increased size and complexity could be a factor in the lower performance. An alternate interpretation is that perhaps the Government customer is more difficult to work for than the Prime Contractor customer. This survey did not collect sufficient evidence to address these hypotheses.

In question *Prod02*, acquirers were categorized as either Army, Navy, Air Force, NASA, DHS, DARPA, Other Government, Commercial, or Other, as noted in Section 5.1.2. Project Performance, as defined in Section 5.1.5.4, was evaluated in each category, as shown in Figure 37.

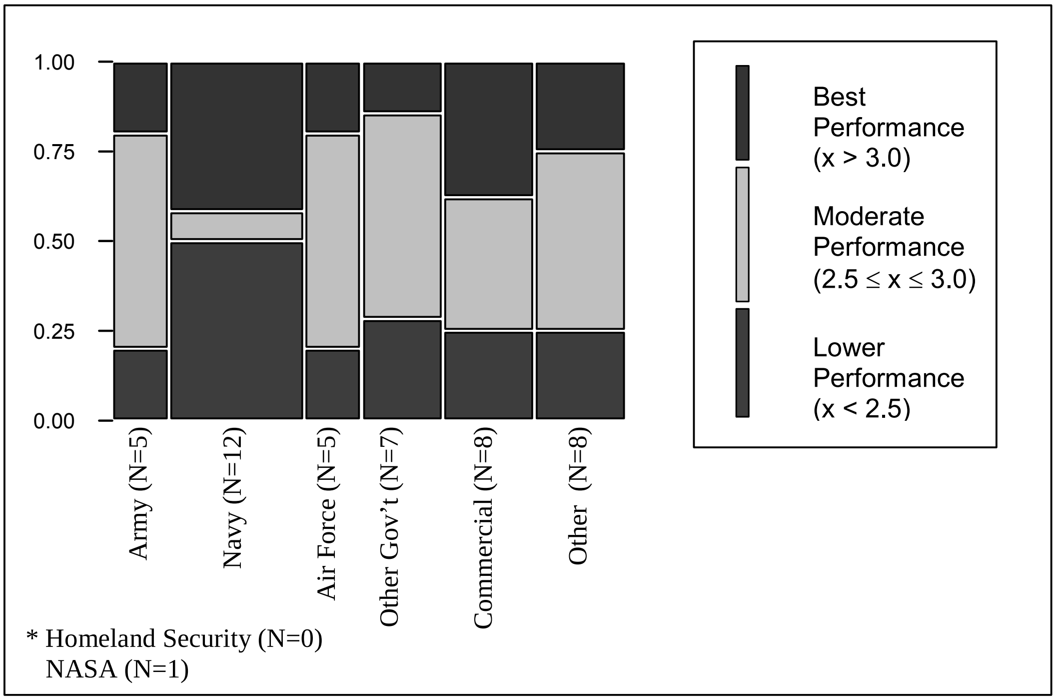


Figure 37: Relationship Between Acquiring Organization and Performance (***Perf*** *Versus* ***Prod02****)*

There are very few projects in each category, so little can be said here with confidence. Projects that classified themselves in the Commercial category seem to have slightly better success than most of the others. At least based on this data, the Navy may lack a middle ground, with the majority of their projects delivering either Best Performance or Lower Performance, but very few delivering Moderate performance. Once again, care should be taken not to over interpret these differences.

In question *Prod04*, the resulting product's location within a system's hierarchy was categorized as either System-of-Systems, System, Subsystem, Component, Process, Material, or Other, as noted in Section 5.1.2.

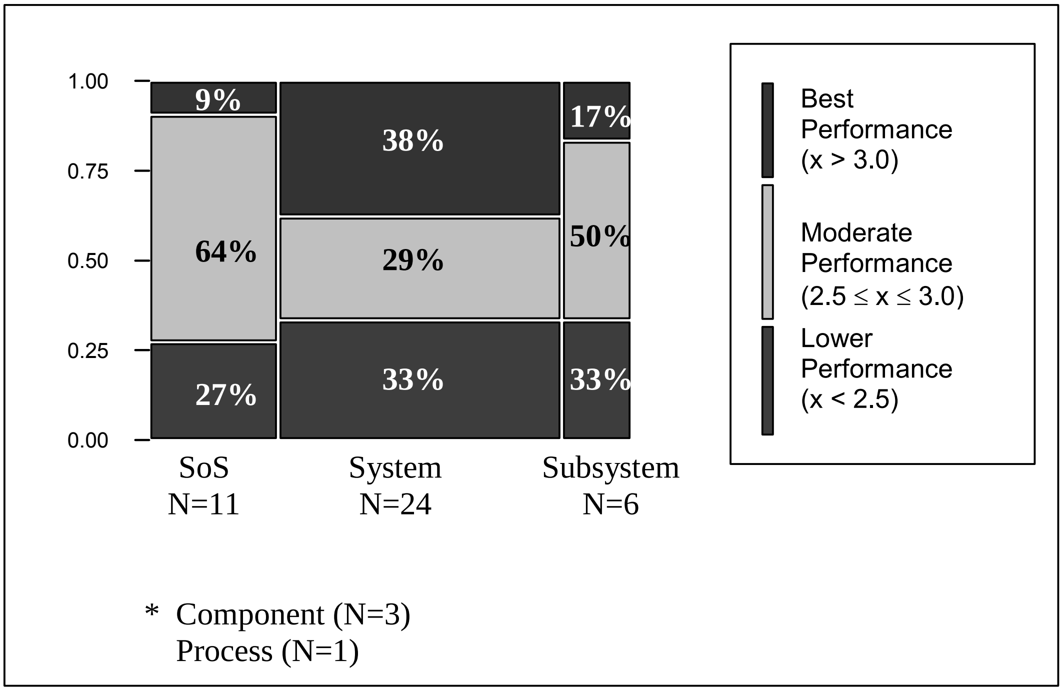


Figure 38: Relationship Between Position in Systems Hierarchy and Performance (***Perf*** *Versus* ***Prod04****)*

As shown in Figure 38, when compared with the Project Performance composite measure defined in Section 5.1.5.4, this survey question shows that projects delivering Systems-of-Systems are least likely (9%) to show Best Performance. Of the projects that deliver Systems, 38% show Best Performance. Of the projects that deliver Subsystems, the percentage showing Best Performance drops to 17%. For all of the above (SoS, Systems, and Subsystems) about one in three of the projects shows lower Performance. The numbers of projects supplying Components, Processes, or Materials are too small to provide meaningful insight, and too small to honor our promise of non-disclosure made to the survey participants.

In question *Cont08*, the project's utilization of Subcontractors was identified, as noted in Section 5.1.2. Its relationship with the Project Performance composite measure defined in Section 5.1.5.4, is shown in Figure 39.

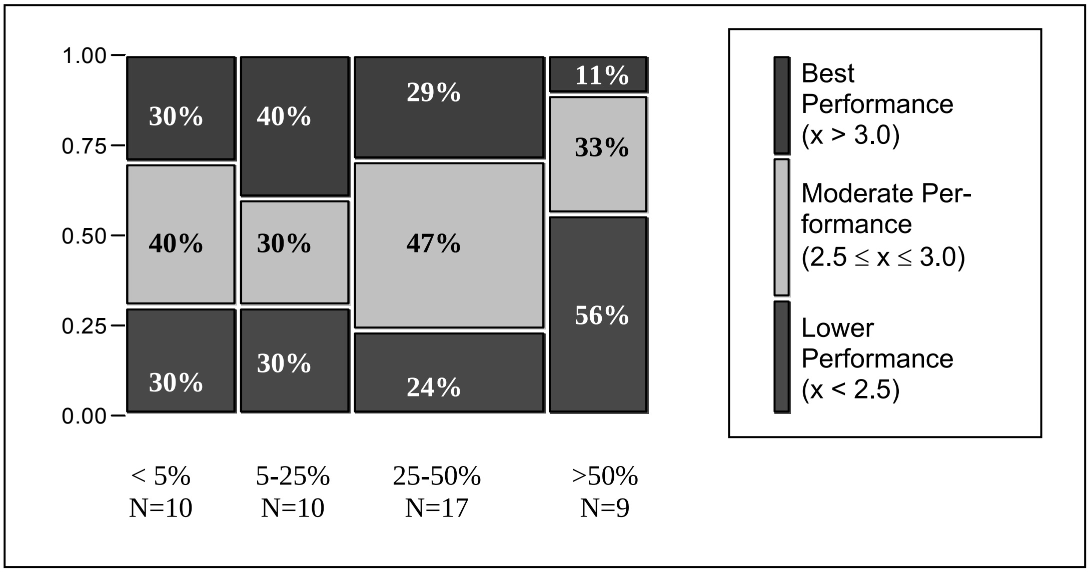


*Figure 39: Relationship Between Subcontracted Percentage and Performance (**Perf** Versus **Cont08**)*

The percentage of subcontracted effort varied across the project sample with 10 projects subcontracting less than 5% of the effort, 10 projects subcontracting 5% to 25% of the effort, 17 projects subcontracting 25% to 50% of the effort and 9 projects subcontracting more than 50% of the effort. No clear trend is apparent among the projects subcontracting less than 50% of the effort, regardless of the amount of subcontracting. However, projects exhibiting Lower Performance increases markedly to 56% among those projects subcontracting more than 50% of their project effort. Likewise, the portion exhibiting Best Performance decreases to only 11%. Possible interpretations of this observation include

- Larger subcontracting efforts require more coordination among subcontractors, increasing the difficulty of project execution.
- Subcontracting larger amounts of the project decreases the control that can be exercised on the project.

In question *Cont14a*, the project's Systems Engineering content was evaluated, as noted in Section 5.1.2. This parameter showed a strong negative relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 40.

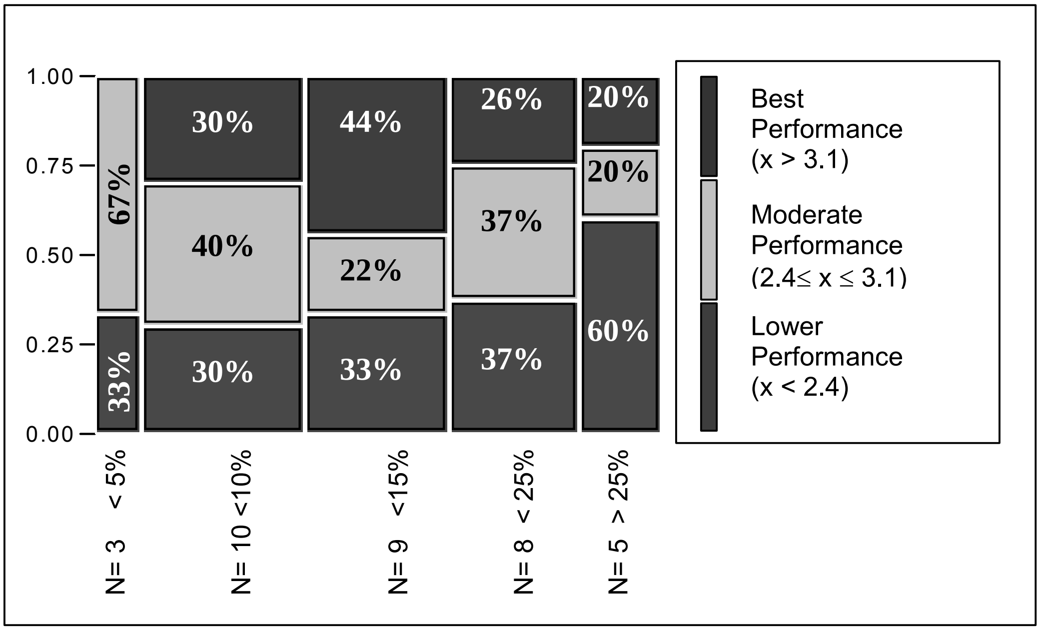


Figure 40: Relationship Between Systems Engineering Content and Performance (***Perf*** *Versus* ***Cont14a****)*

However, this negative relationship is somewhat misleading. Analysis of the responses to question Cont14a reveals that the projects with SE content greater than 25% seem to be a different type of project (see APPENDIX D, Section D.1). Excluding these projects eliminates the negative relationship. In interpreting Figure 40, we will concentrate primarily on the projects with SE content < 25%.

Planned Systems Engineering effort varied across the project sample with three projects having SE Content < 5%, 10 having SE Content from 5 to 10%, nine having SE Content from 10 to 15%, and eight having SE Content from 15 to 25%. Regardless of the amount of SE content, approximately one-third of the projects exhibited Lower Performance. The largest percentage of projects achieving the Best Performance seemed to occur for SE Content levels from 10 to 15%. However, care should be exercised in interpreting the meaning of the difference based on such a small number of cases in each of the categories of SE Content.

5.2.2.1 CMMI-Based Process Management Versus Performance (SEC_{CMMI} vs. *Perf*)

The CMMI-related supplier capability composite measure described in Section 5.1.2.1 showed weak positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 41.

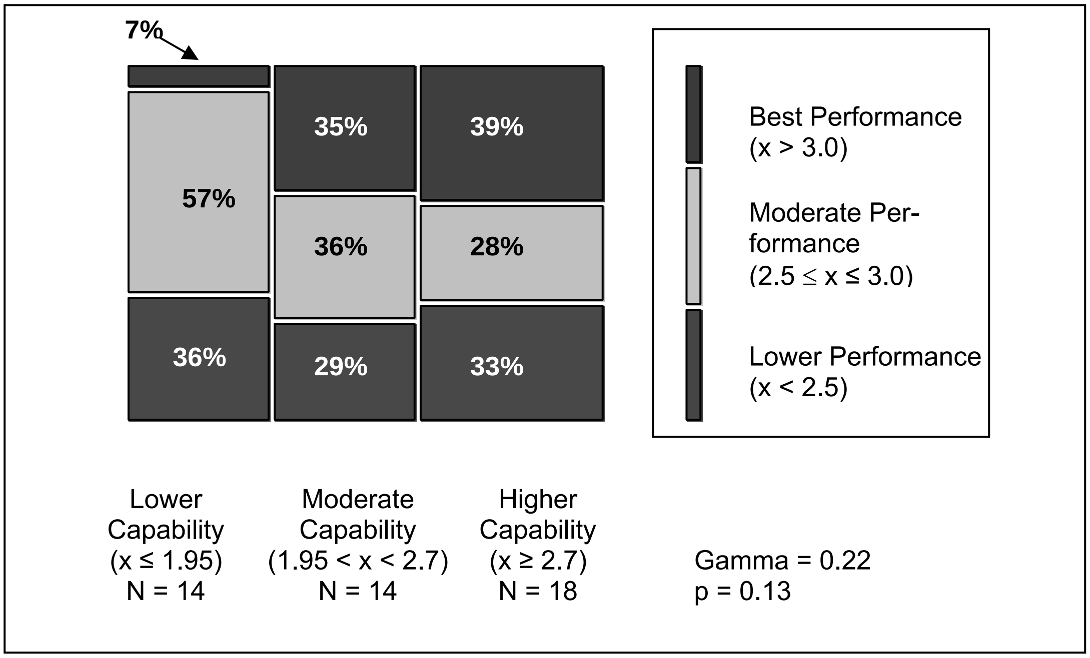


*Figure 41: Relationship Between Supplier CMMI-Related Capability and Project Performance (**Perf** Versus **SEC_{CMMI}**)*

CMMI-related capability varied across the project sample with 14 projects exhibiting lower CMMI-related capability, 14 exhibiting moderate CMMI-related capability, and 18 exhibiting higher CMMI-related capability. A weak positive relationship between ***SEC_{CMMI}*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, 7% of the projects with lower CMMI-related capability exhibited Best Performance, while 39% of projects with higher CMMI-related capability exhibited Best Performance. However, there are only small differences in Lower Performance as a function of Supplier CMMI-related capability.

A *Gamma* value of 0.22 indicates that there is a weak positive relationship between Project Performance and the elements of CMMI-related capabilities addressed in this survey. A *p* value of 0.13 indicates that this interpretation is not reliable since there exists a 13% probability that a relationship of this magnitude could spontaneously occur by chance alone.

There are many possible reasons for this relatively weak statistical relationship. In particular, two of the three questions that are combined in the measure of Supplier CMMI-related capability ask about organizational maturity level, rather than about the Systems Engineering management and engineering capabilities of the projects where the development work is done.[6] As noted throughout Section 5.2.3, the statistical relationships with Project Performance are considerably stronger for most of the measures of supplier Systems Engineering Capability.

[6] The full nature of the relationship between organizational maturity and project capabilities needs to be analyzed more fully elsewhere. The data from this survey are only tangential to a fuller analysis; however, they do appear to show some significant differences in project SE Capability as a function of organizational maturity level.

5.2.2.2 Process Improvement vs. Performance (SEC_{IMP} versus Perf)

The Process Improvement supplier capability measure is described in Section 5.1.2.3. Its relationship with the Project Performance composite measure defined in Section 5.1.5.4 is shown in Figure 42.

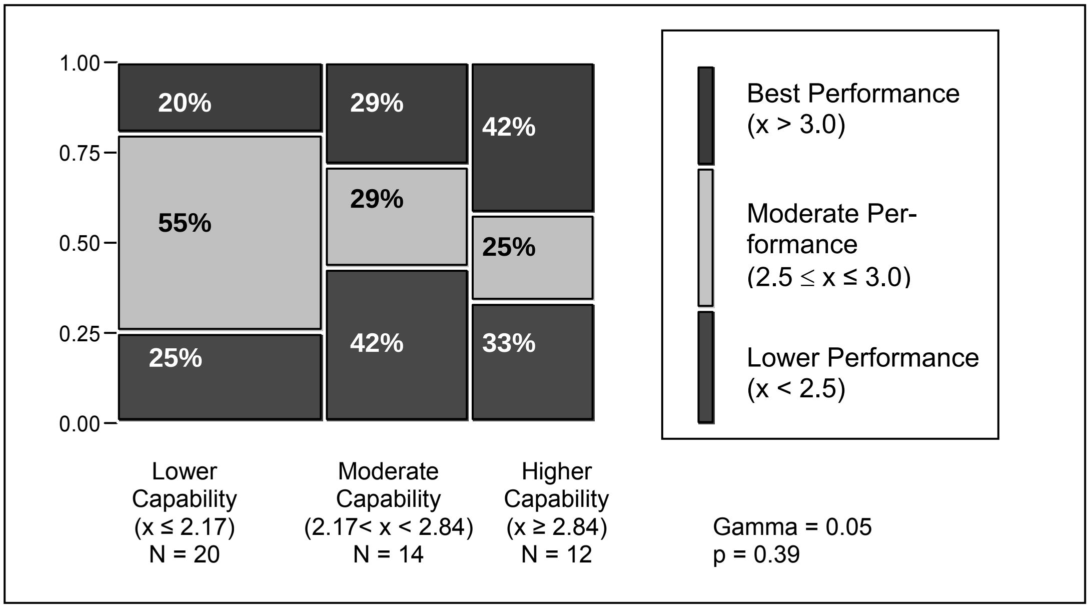


*Figure 42: Relationship between Process Improvement capability and Project Performance (**Perf** Versus **SEC_{IMP}**)*

Process Improvement capability varied across the project sample with 20 projects exhibiting lower Process Improvement capability, 14 exhibiting moderate Process Improvement capability, and 12 exhibiting higher Process Improvement capability. Overall, a very weak positive relationship between ***SEC_{IMP}*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, 20% of the projects with lower Process Improvement capability exhibited Best Performance, while 42% of projects with higher Process Improvement capability exhibited Best Performance. However, the relationship is less consistent with respect to Lower Performance, where the projects with the least Process Improvement capability in fact fared somewhat better than did those that exhibited moderate or higher capability.

A *Gamma* value of 0.05 indicates that there is a weak to non-existent positive overall relationship between Project Performance and the elements of Process Improvement addressed in this survey. A *p* value of 0.39 indicates that there is a 39% probability that a relationship of this magnitude could spontaneously occur by chance alone.

5.2.2.3 Prior Experience vs. Performance (SEC_{EXP} vs. *Perf*)

The Prior Experience composite measure is described in Section 5.1.2.2. Its relationship with the Project Performance composite measure defined in Section 5.1.5.4 is shown in Figure 43.

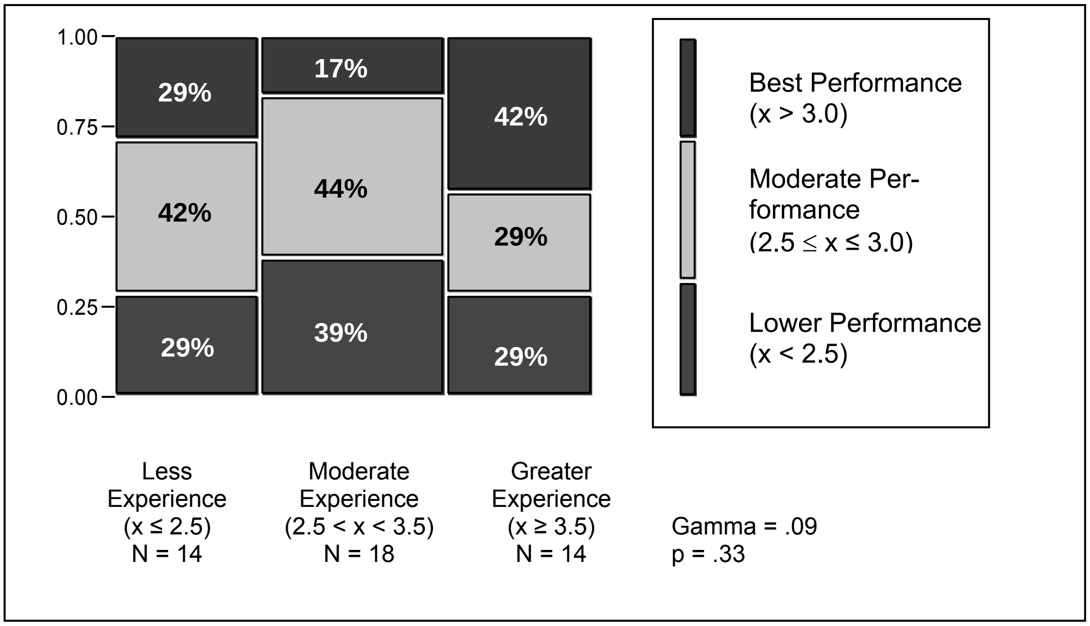


*Figure 43: Relationship between Prior Experience and Project Performance (**Perf** Versus **SEC**$_{EXP}$)*

Prior Experience varied across the project sample with 14 projects exhibiting lower Prior Experience, 18 exhibiting moderate Prior Experience, and 14 exhibiting higher Prior Experience. Those projects with more experience were somewhat more likely to demonstrate Best Performance; however, the other differences are not consistent.

5.2.3 Relationships between Systems Engineering Capabilities (*SEC*) and Performance (*Perf*)

To identify the relationship between Systems Engineering Capabilities and Project Performance, we will examine the following relationships:

- IPT-based capability versus Performance ($\boldsymbol{SEC_{IPT}}$ versus ***Perf***)
- Project Planning versus Performance ($\boldsymbol{SEC_{PP}}$ versus ***Perf***)
- Project Monitoring and Control versus Performance ($\boldsymbol{SEC_{PMC}}$ versus ***Perf***)
- Risk Management versus Performance ($\boldsymbol{SEC_{RSKM}}$ versus ***Perf***)
- Requirements Development and Management versus Performance ($\boldsymbol{SEC_{REQ}}$ versus ***Perf***)
- Trade Studies versus Performance ($\boldsymbol{SEC_{TRADE}}$ versus ***Perf***)
- Product Architecture versus Performance ($\boldsymbol{SEC_{ARCH}}$ versus ***Perf***)
- Technical Solution (= SEC_{TRADE} + SEC_{ARCH}) versus Performance ($\boldsymbol{SEC_{TS}}$ versus ***Perf***)
- Product Integration versus Performance ($\boldsymbol{SEC_{PI}}$ versus ***Perf***)
- Verification versus Performance ($\boldsymbol{SEC_{VER}}$ versus ***Perf***)
- Validation versus Performance ($\boldsymbol{SEC_{VAL}}$ versus ***Perf***)
- Configuration Management versus Performance ($\boldsymbol{SEC_{CM}}$ versus ***Perf***)
- Total Systems Engineering Capability versus Performance (***SEC*** versus ***Perf***)
- Req'ts and Technical Solution Capability versus Performance ($\boldsymbol{SEC_{R+TS}}$ versus ***Perf***)

5.2.3.1 IPT-related capability versus Performance (SEC_{IPT} versus *Perf*)

The Integrated Product Team (IPT) supplier capability composite measure described in Section 5.1.3.1 showed a moderately strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 44.

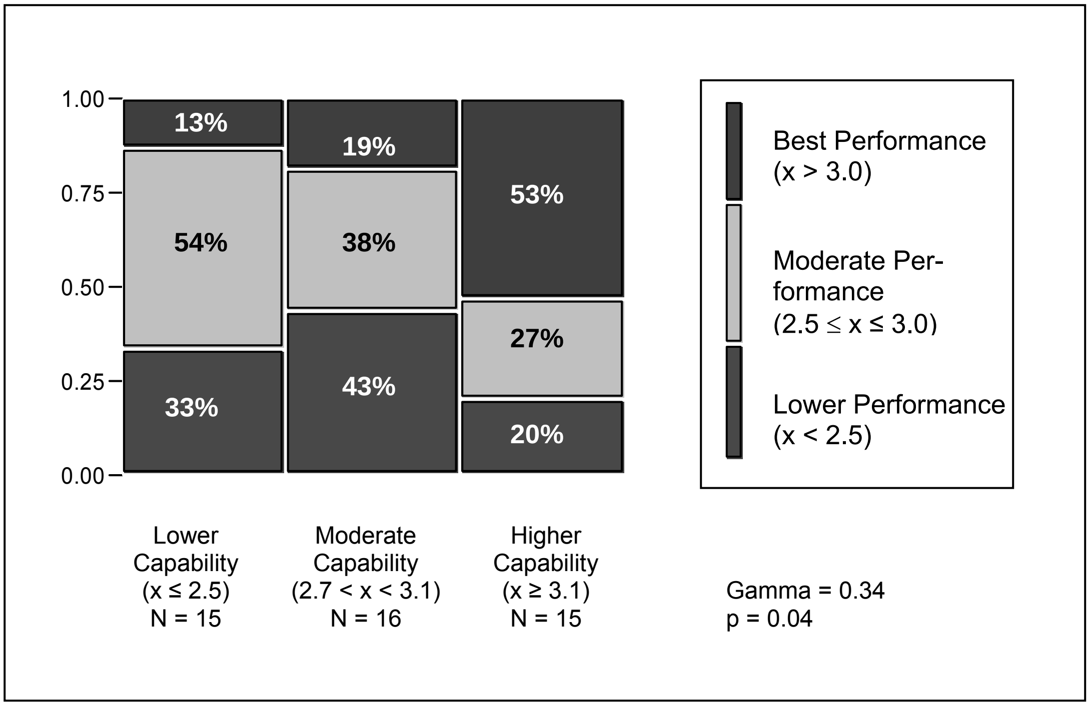


*Figure 44: Relationship Between Supplier IPT Capability and Project Performance (**Perf** Versus **SEC_{IPT}**)*

Utilization of IPTs varied across the project sample with 15 projects exhibiting low IPT utilization, 16 exhibiting moderate IPT utilization, and 15 exhibiting high IPT utilization. A moderately strong positive relationship between ***SEC_{IPT}*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 13% of projects with low IPT utilization exhibited Best Performance, while 53% of projects with high IPT utilization exhibited Best Performance. Similarly, only 20% of projects with High IPT utilization exhibited Lower Performance. However, the differences between lower and moderate performance are less consistent among the projects that exhibit lower as compared to moderate Supplier IPT capability.

A *Gamma* value of 0.34 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Integrated Project Team deployment addressed in this survey. A *p* value of 0.04 indicates that there is a 4% probability that a relationship of this magnitude could spontaneously occur by chance alone.

Among Best Performing Projects, the percentage of projects exhibiting high IPT process capability (53%) is among the highest across the process areas analyzed. This may indicate the value of integrated teams and collaboration in helping to produce successful project outcomes.

5.2.3.2 Project Planning versus Performance (SEC_{PP} versus *Perf*)

The supplier's Project Planning capability composite measure described in Section 5.1.3.2 showed a weak positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 45.

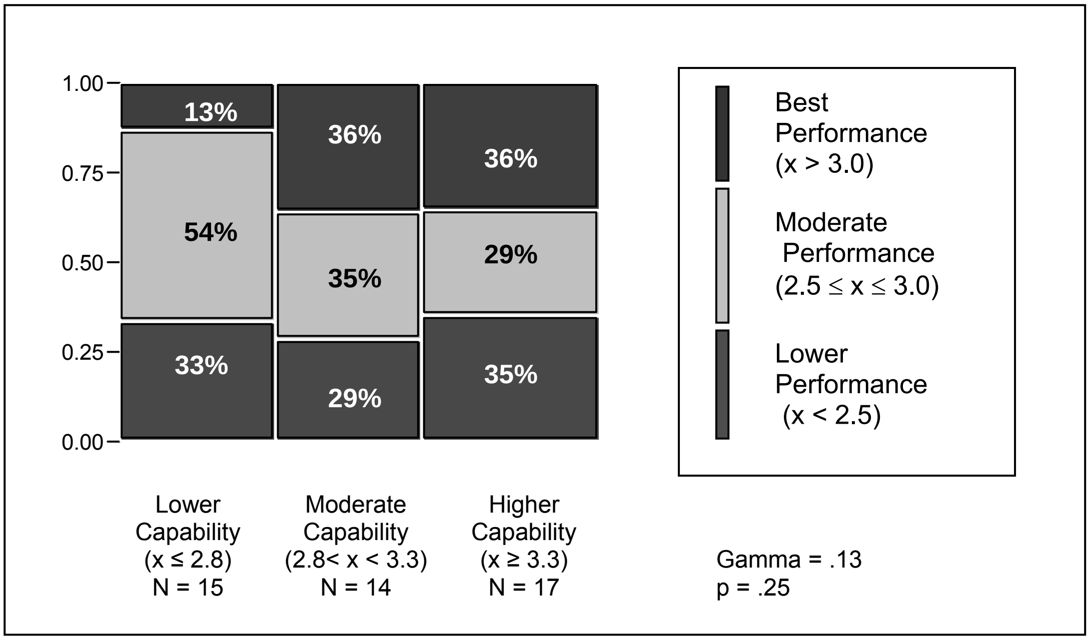


*Figure 45: Relationship between Supplier Project Planning Capability and Project Performance (**Perf** Versus **SEC_{PP}**)*

Project Planning capability varied across the project sample with 13 projects exhibiting lower Project Planning capability, 14 exhibiting moderate Project Planning capability, and 19 exhibiting higher Project Planning capability. A weak positive relationship between SEC_{PP} and Perf is evident. Among the projects exhibiting Best Performance, only 15% of the projects with lower Project Planning capability exhibited Best Performance, while 37% of projects with the higher Project Planning capability exhibited Best Performance. However, the higher capability projects were as likely to exhibit lower performance as high. This inconsistency may be due to misinterpretation by the responding projects of the intended meaning of the survey questions or to other measurement error. Moreover, regardless of the reasons, no single measure can be expected to account for all of the variation in Project Performance.

A *Gamma* value of 0.13 indicates that there is a weak positive relationship between Project Performance and the elements of Project Planning addressed in this survey. A *p* value of 0.24 indicates that there is a 24% probability that a relationship of this magnitude could spontaneously occur by chance alone.

5.2.3.3 Project Monitoring and Control versus Performance (SEC_{PMC} versus *Perf*)

The Project Monitoring and Control supplier capability composite measure described in Section 5.1.3.3 showed weak negative relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 46.

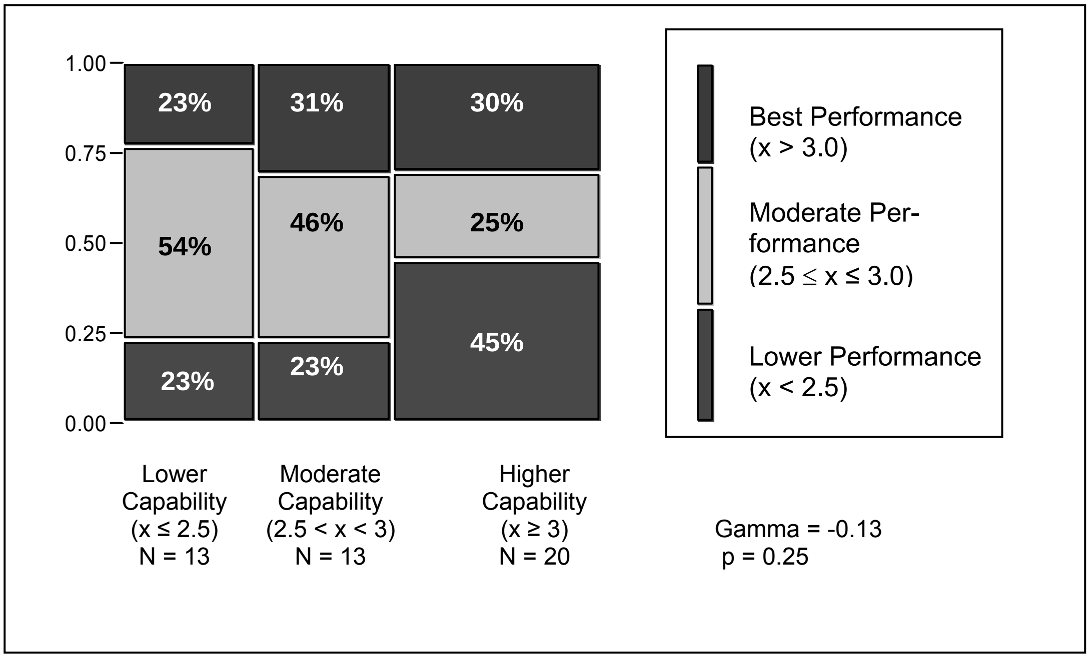


*Figure 46: Relationship Between Supplier Project Monitoring and Control Capability and Project Performance (**Perf** Versus **SEC$_{PMC}$**)*

Project Monitoring and Control capability varied across the project sample with 13 projects exhibiting lower Project Monitoring and Control capability, 13 exhibiting moderate Project Monitoring and Control capability, and 20 exhibiting higher Project Monitoring and Control capability. A weak negative relationship between ***SEC$_{PMC}$*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, a positive influence of ***SEC$_{PMC}$*** was seen, with 23% of the projects with the lower Project Monitoring and Control capability exhibiting Best Performance, while 30% of projects with higher Project Monitoring and Control capability exhibited Best Performance. The percentage of poorly performing projects showed negative influences of ***SEC$_{PMC}$*** on Project Performance. Twenty-three percent of the projects with lower Project Monitoring and Control capability exhibited lower Performance, while 45% of projects with higher Project Monitoring and Control capability exhibited lower Performance.

A *Gamma* value of -0.13 indicates that there is a weak negative relationship between Project Performance and the elements of Project Monitoring and Control addressed in this survey. A *p* value of 0.25 indicates that there is a 25% probability a relationship of this magnitude could spontaneously occur by chance alone.

This finding raises the question, “How could more monitoring and control degrade Project Performance?” But perhaps that is the wrong question to ask. Remember that the analysis shows that there is a relationship between Performance and Project Monitoring and Control; it does not reveal which is the cause and which is the effect. When a project encounters difficulties, often increased scrutiny is one of the first actions taken. Thus, rather than interpreting the results as

“Increased Project Monitoring and Control results in Reduced Project Performance”

The more correct interpretation may be

"Poorly Performing projects result in Increased Project Monitoring and Control."

5.2.3.4 Risk Management versus Performance (SEC_{RSKM} versus *Perf*)

The Risk Management supplier capability composite measure described in Section 5.1.3.4 showed a moderately strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 47.

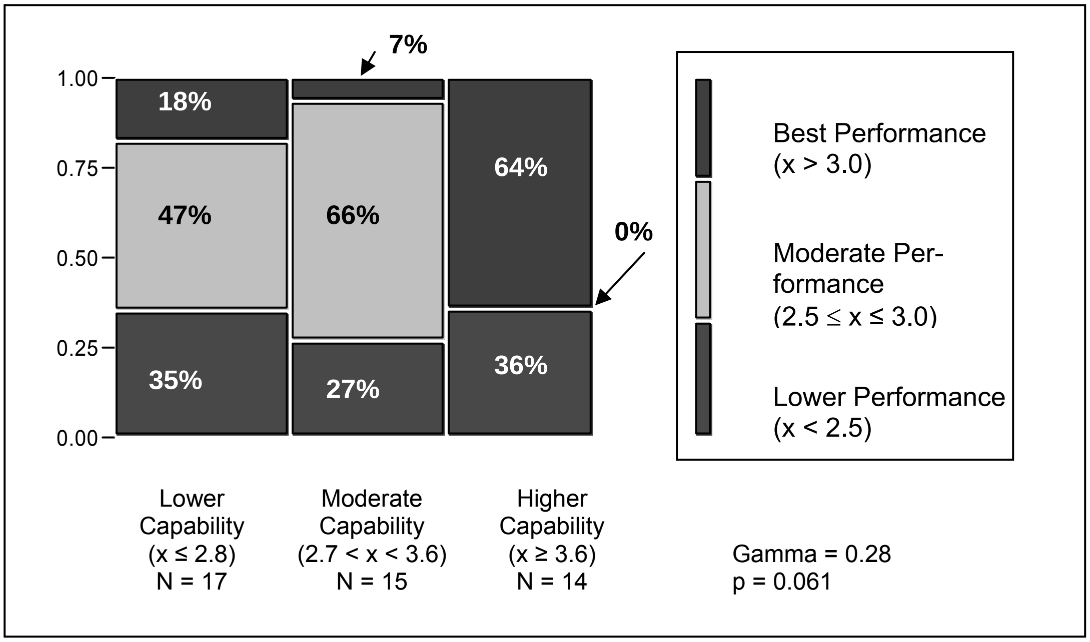


*Figure 47: Relationship Between Supplier Risk Management Capability and Project Performance (**Perf** Versus **SEC_{RSKM}**)*

Risk Management capability varied across the project sample with 17 projects exhibiting lower Risk Management capability, 15 exhibiting moderate Risk Management capability, and 14 exhibiting higher Risk Management capability. A moderately strong positive relationship between ***SEC_{RSKM}*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 18% of the projects with lower Risk Management capability exhibited Best Performance, while 64% of projects with higher Risk Management capability exhibited Best Performance. The percentage of poorly performing projects remained largely unchanged as a function of Risk Management capability. However, among the projects with lower or moderate Risk Management capabilities, a significant number exhibited only moderate Project Performance.

A *Gamma* value of 0.28 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Risk Management addressed in this survey. A *p* value of 0.06 indicates that there is a 6% probability a relationship of this magnitude could spontaneously occur by chance alone.

Nearly 2/3 of the Best Performing projects exhibited a higher capability in Risk Management. In fact, among Best Performing projects, the composite score for Risk Management capability (64%) was the highest among all analyzed process areas by a significant margin. This may suggest the value of effective Risk Management in producing successful project outcomes.

5.2.3.5 Requirements Development versus Performance (SEC_{REQ} versus *Perf*)

The Requirements Development and Management supplier capability composite measure described in Section 5.1.3.5 showed a moderately strong positive relationship with the Project Performance measure defined in Section 5.1.5.4, as shown in Figure 48.

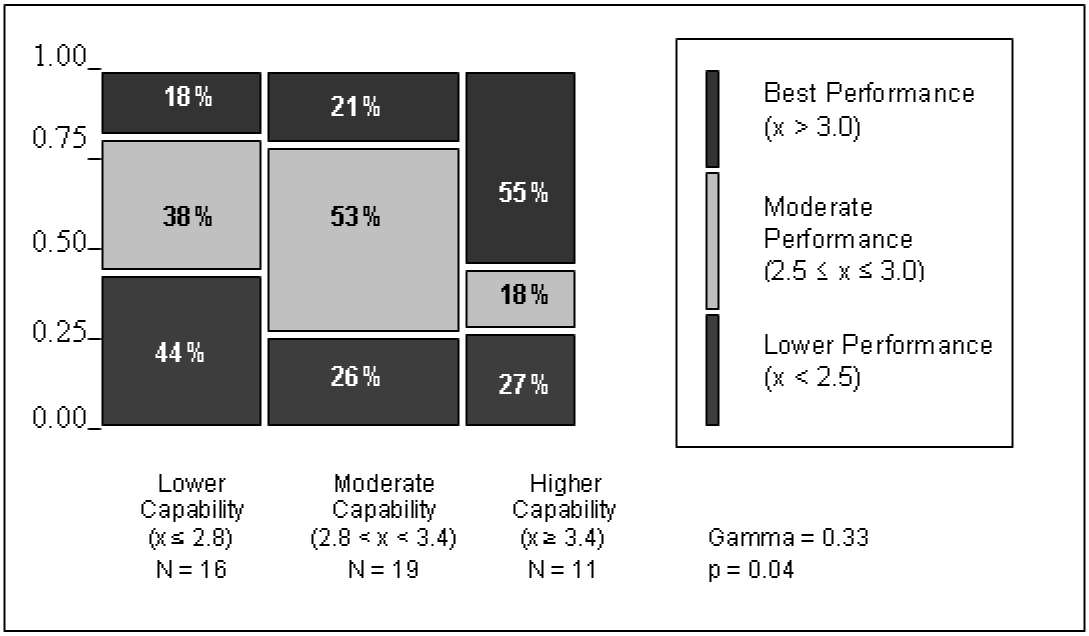


*Figure 48: Relationship Between Supplier Requirements Capabilities and Project Performance (**Perf** Versus **SEC_{REQ}**)*

Requirements capability varied across the project sample with 16 projects exhibiting lower Requirements capability, 19 exhibiting moderate Requirements capability, and 11 exhibiting higher Requirements capability. A moderately strong positive relationship between ***SEC_{REQ}*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 18% of the projects with lower Requirements capability exhibited Best Performance, while 55% of projects with higher Requirements capability exhibited Best Performance. Similarly, 44% of the projects with the lower Requirements capability exhibited lower Performance, while only 27% of projects with the higher Requirements capability exhibited lower Performance.

A *Gamma* value of 0.33 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Requirements Development and Management addressed in this survey. A *p* value of 0.04 indicates that there is a 4% probability that a relationship of this magnitude could spontaneously occur by chance alone.

Over half of the Higher Performing Projects exhibited a higher capability in Requirements Development and Management, suggesting the value of effective requirements management in producing successful project outcomes

5.2.3.6 Trade Studies versus Performance (SEC_{TRADE} versus *Perf*)

The Trade Studies supplier capability composite measure described in Section 5.1.3.6 showed a moderately strong to strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 49.

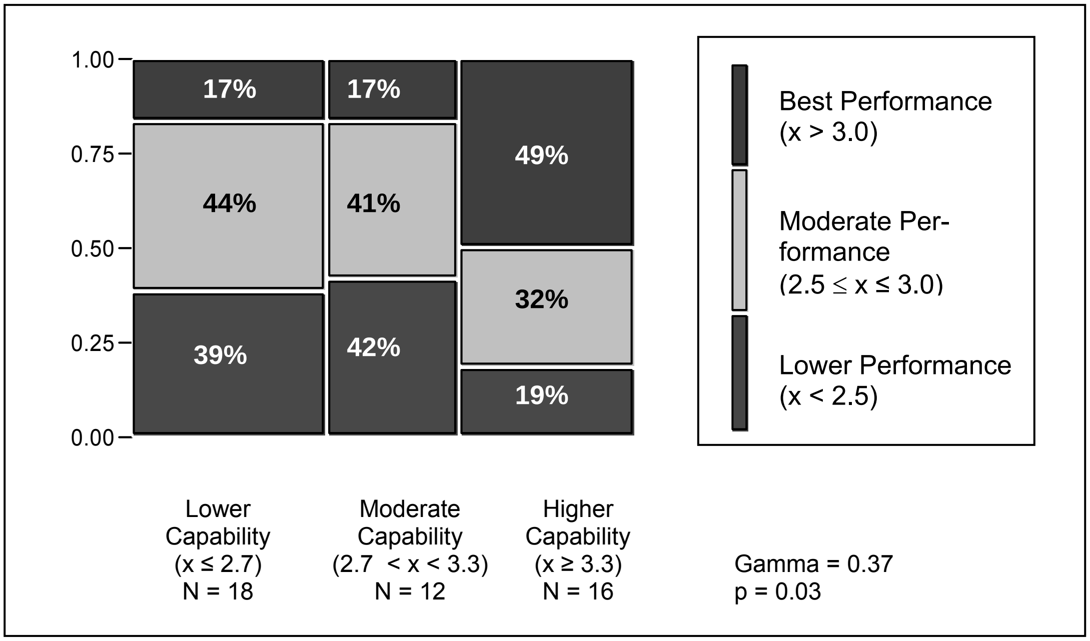


*Figure 49: Relationship Between Supplier Trade Study Capabilities and Project Performance (**Perf** Versus $\mathbf{SEC_{TRADE}}$)*

Trade Study capability varied across the project sample with 18 projects exhibiting lower Trade Study capability, 12 exhibiting moderate Trade Study capability, and 16 exhibiting higher Trade Study capability. A moderately strong to strong positive relationship between $\mathbf{SEC_{TRADE}}$ and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 17% of the projects with lower Trade Study capability exhibited Best Performance, while 50% of projects with higher Trade Study capability exhibited Best Performance. Similarly, 39% of the projects with lower Trade Study capability exhibited lower Performance, while only 19% of projects with higher Trade Study capability exhibited lower Performance.

A *Gamma* value of 0.37 indicates that there is a moderately strong to strong positive relationship between Project Performance and the elements of Trade Study Capabilities addressed in this survey. A *p* value of 0.03 indicates that there is a 3% probability that a relationship of this magnitude could spontaneously occur by chance alone.

5.2.3.7 Product Architecture versus Performance (SEC_{ARCH} versus *Perf*)

The Product Architecture supplier capability composite measure described in Section 5.1.3.7 showed a moderately strong to strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 50.

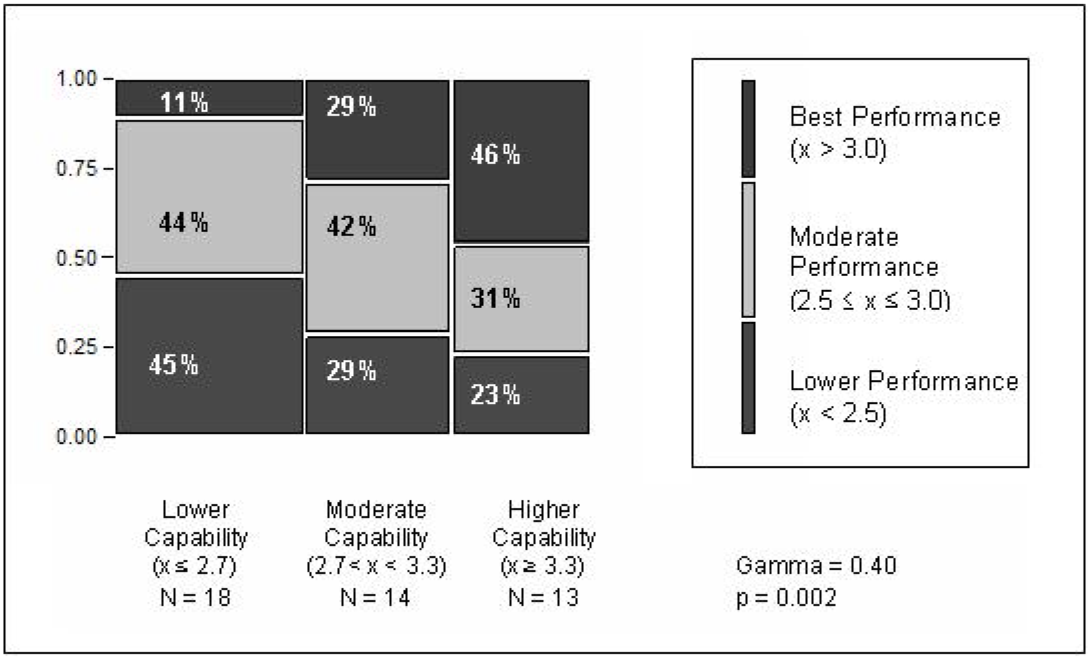


*Figure 50: Relationship Between Supplier Product Architecture Capabilities and Project Performance (**Perf** Versus $\boldsymbol{SEC_{ARCH}}$)*

Product Architecture capability varied across the project sample with 18 projects exhibiting lower Product Architecture capability, 14 exhibiting moderate Product Architecture capability, and 13 exhibiting higher Product Architecture capability. A moderately strong to strong positive relationship between $\boldsymbol{SEC_{ARCH}}$ and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 11% of the projects with the lower Product Architecture capability exhibited Best Performance, while 46% of projects with the higher Product Architecture capability exhibited Best Performance. Similarly, 44% of the projects with the lower Product Architecture capability exhibited lower Performance, while only 23% of projects with the higher Product Architecture capability exhibited lower Performance.

A *Gamma* value of 0.40 indicates that there is a moderately strong to strong positive relationship between Project Performance and the elements of Product Architecture addressed in this survey. A *p* value of 0.02 indicates that there is a 2% probability that a relationship of this magnitude could spontaneously occur by chance alone.

This data seems to substantiate the widely-held belief in the importance of effective architectural practices in producing successful project outcomes.

5.2.3.8 Technical Solution (= SEC_{TRADE} + SEC_{ARCH}) versus Performance (SEC_{TS} versus *Perf*)

The Technical Solution supplier capability composite measure described in Section 5.1.3.8 showed a moderately strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 51.

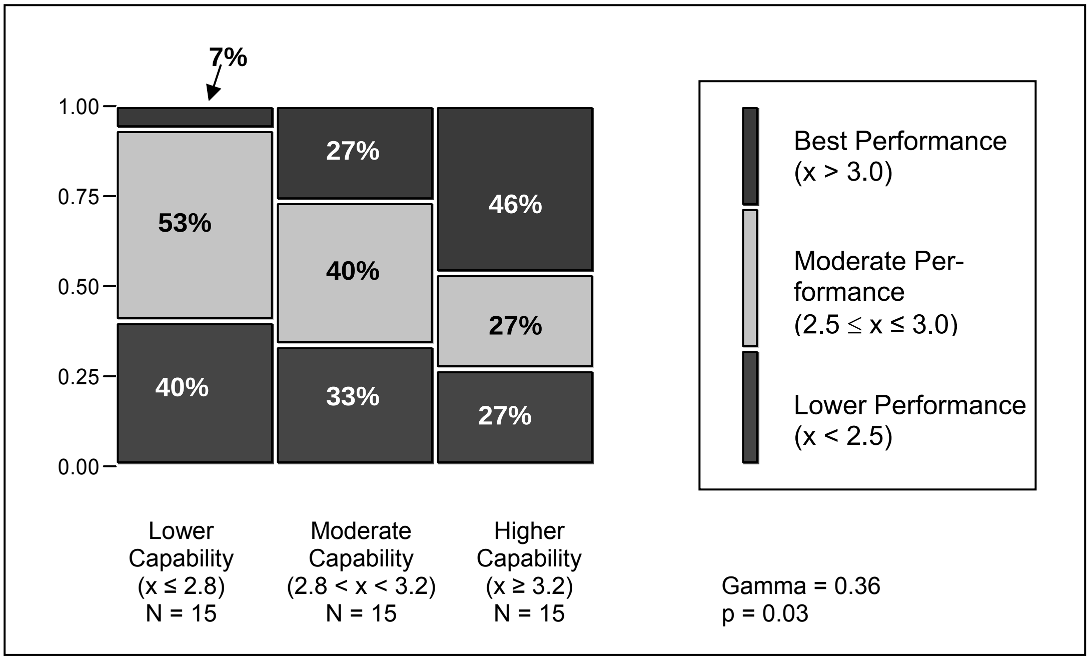


*Figure 51: Relationship Between Supplier Technical Solution Capabilities and Project Performance (**Perf** Versus **SEC**$_{TS}$)*

Technical Solution capability varied across the project sample with 15 projects exhibiting lower Technical Solution capability, 15 exhibiting moderate Technical Solution capability, and 15 exhibiting higher Technical Solution capability. A moderately strong positive relationship between ***SEC***$_{TS}$ and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 7% of the projects with the lower Technical Solution capability exhibited Best Performance, while 46% of projects with the higher Technical Solution capability exhibited Best Performance. Consistent, but smaller differences were seen among the lower Performance projects. Forty percent of the projects with lower Technical Solution capability exhibited lower Performance, while only 27% of projects with higher Technical Solution capability exhibited lower Performance.

A *Gamma* value of 0.36 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Product Architecture addressed in this survey. A *p* value of 0.03 indicates that there is a 3% probability a relationship of this magnitude could spontaneously occur by chance alone.

5.2.3.9 Product Integration versus Performance (SEC$_{PI}$ versus *Perf*)

The Product Integration supplier capability measure described in Section 5.1.3.9 showed a weak positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 52.

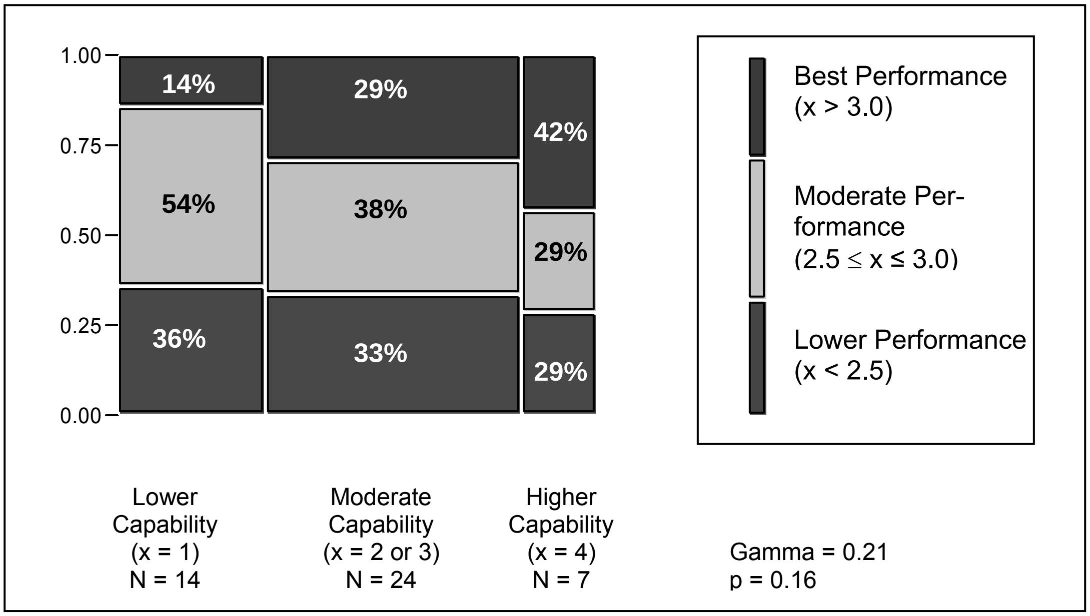


*Figure 52: Relationship Between Supplier Product Integration and Project Performance (**Perf** Versus **SEC**$_{PI}$)*

Product Integration capability varied across the project sample with 14 projects exhibiting lower Product Integration capability, 24 exhibiting moderate Product Integration capability, and 7 exhibiting higher Product Integration capability. A weak positive relationship between ***SEC***$_{PI}$ and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 14% of the projects with the lower Product Integration capability exhibited Best Performance, while 43% of projects with the higher Product Integration capability exhibited Best Performance. Consistent, but much smaller differences were seen among the lower Performance projects. Thirty-six percent of the projects with lower Product Integration capability exhibited lower Performance, while only 29% of projects with higher Product Integration capability exhibited lower Performance.

Note, however, that the weak relationship in this instance may be due to the fact that the Product Integration capability measure is based on only a single survey question. Moreover, the answers to that question are not evenly distributed across the possible response categories from “disagree strongly” to “agree strongly.” It is quite possible that a composite measure of Product Integration capability would reduce the measurement error typically found in a single survey question. Of course we cannot know from this survey, but the statistical relationship with Project Performance then might well be comparable to those found with many of the other similar Systems Engineering Capability measures in this survey.

A *Gamma* value of 0.21 indicates that there is a weak positive relationship between Project Performance and the elements of Product Architecture addressed in this survey. A *p* value of 0.16 indicates that there is a 16% probability that a relationship of this magnitude could spontaneously occur by chance alone.

5.2.3.10 Verification versus Performance (SEC_{VER} versus *Perf*)

The Verification supplier capability composite measure described in Section 5.1.3.10 showed a moderately strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 53.

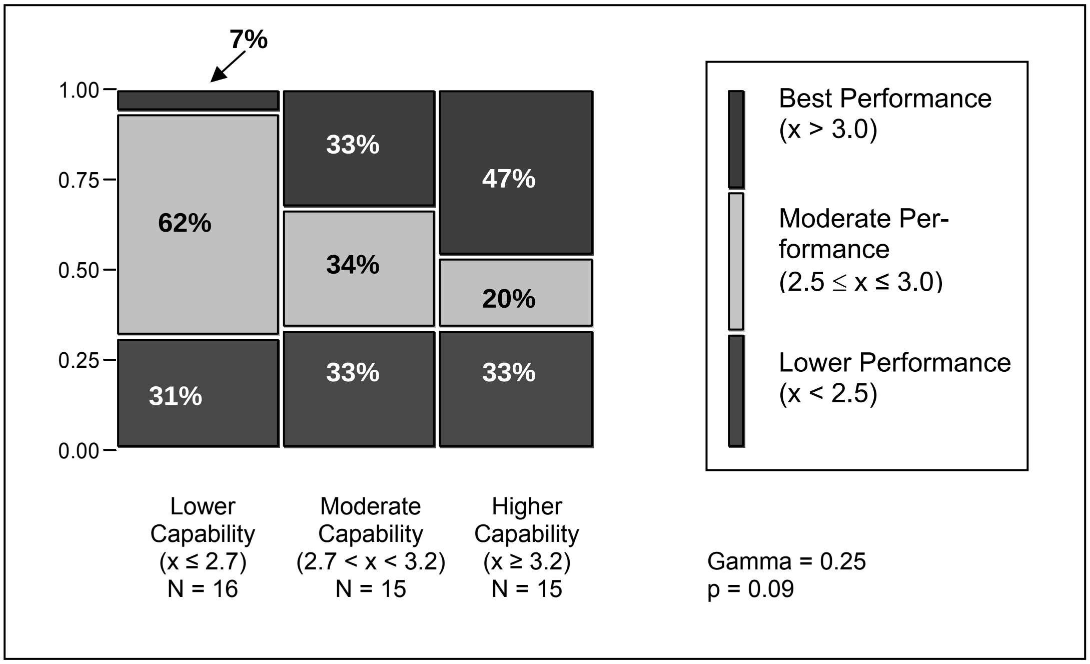


*Figure 53: Relationship Between Supplier Verification Capabilities and Project Performance (**Perf** Versus **SEC**$_{VER}$)*

Verification capability varied across the project sample with 16 projects exhibiting lower Verification capability, 15 exhibiting moderate Verification capability, and 15 exhibiting higher Verification capability. A moderately strong positive relationship between ***SEC***$_{VER}$ and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 7% of the projects with the lower Verification capability exhibited Best Performance, while 47% of projects with the higher Verification capability exhibited Best Performance. The percentage of poorly performing projects remained largely unchanged as a function of Verification capability.

A *Gamma* value of 0.25 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Verification addressed in this survey. A *p* value of 0.09 indicates that there is a 9.3% probability that a relationship of this magnitude could spontaneously occur by chance alone.

5.2.3.11 Validation versus Performance (SEC_{VAL} versus *Perf*)

The Validation supplier capability composite measure described in Section 5.1.3.11 showed a moderately strong positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 54.

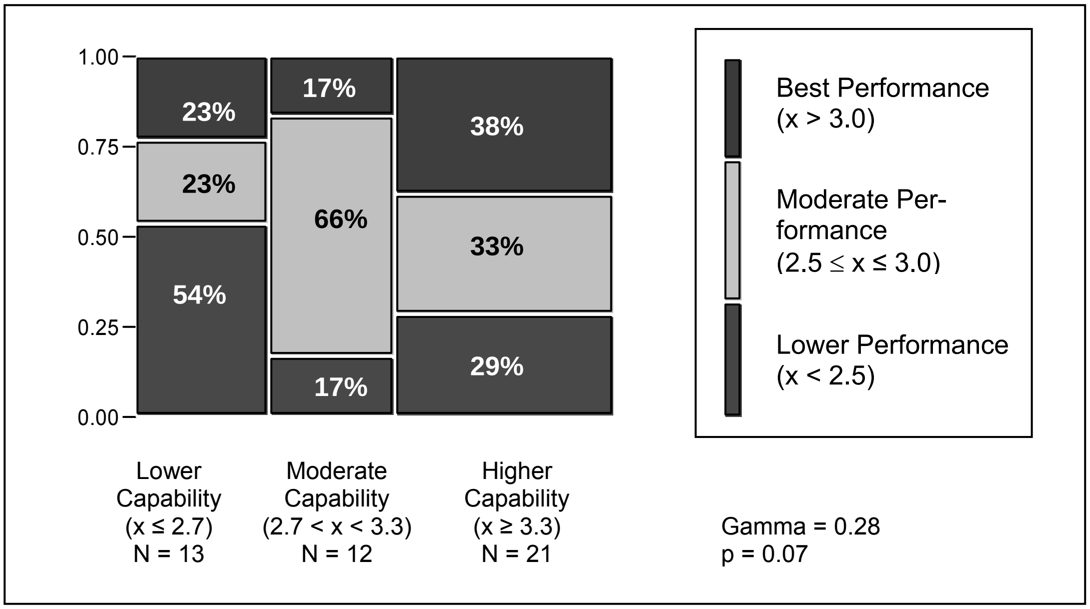


*Figure 54: Relationship Between Supplier Validation Capabilities and Project Performance (**Perf** Versus **SEC**$_{VAL}$)*

Validation capability varied across the project sample with 13 projects exhibiting lower Validation capability, 12 exhibiting moderate Validation capability, and 21 exhibiting higher Validation capability. A moderately strong positive relationship between ***SEC***$_{VER}$ and ***Perf*** is evident. Among projects exhibiting the Best Performance, 23% of the projects with the lower Validation capability exhibited Best Performance, while 38% of projects with the higher Validation capability exhibited Best Performance. Similar differences were seen among the lower Performance projects. Fifty-four percent of the projects with lower Validation capability exhibited lower Performance, while only 29% of projects with higher Validation capability exhibited lower Performance.

A *Gamma* value of 0.28 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Validation addressed in this survey. A *p* value of 0.07 indicates that there is a 7% probability that a relationship of this magnitude could spontaneously occur by chance alone.

It is interesting to note that, among Lower Performing projects, the Validation process area has the greatest percentage of Lower Capability scores (54%), by a significant margin over all other composite process area scores analyzed in this survey. In other words, weaknesses in understanding and validating user needs may be a significant factor in Project Performance issues. However, the inverse inference (i.e., higher Validation process capability leading to higher Project Performance) cannot be supported by the available data.

5.2.3.12 Configuration Management versus Performance (SEC$_{CM}$ versus *Perf*)

The Configuration Management supplier capability composite measure described in Section 5.1.3.12 showed a weak positive relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 55.

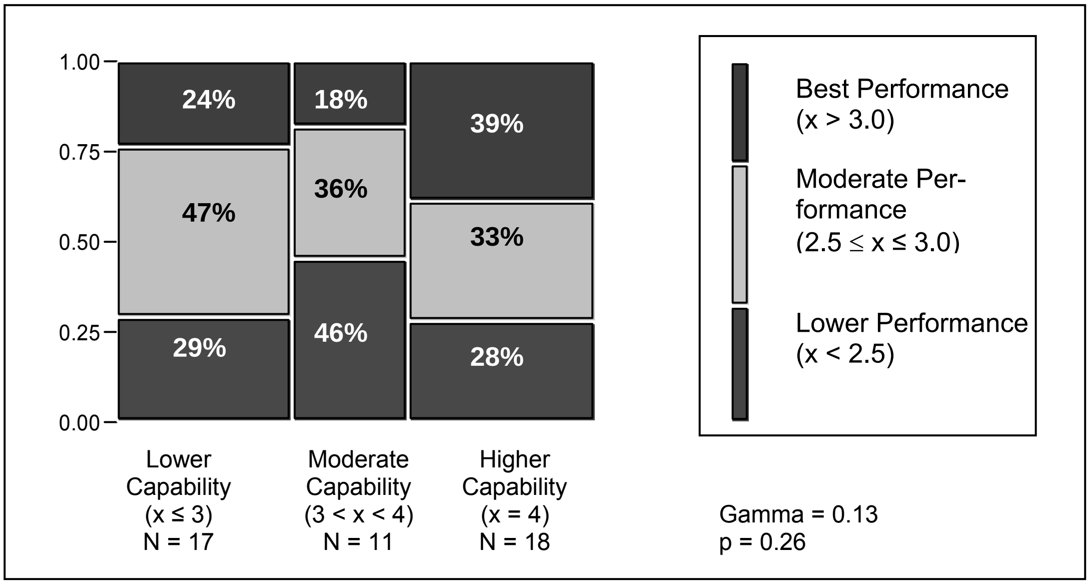


*Figure 55: Relationship Between Supplier Configuration Management Capabilities and Project Performance (**Perf** Versus **SEC_{CM}**)*

Configuration Management capability varied across the project sample with 17 projects exhibiting lower Configuration Management capability, 11 exhibiting moderate Configuration Management capability, and 18 exhibiting higher Configuration Management capability. A weak positive relationship between ***SEC_{CM}*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, 24% of the projects with the lower Configuration Management capability exhibited Best Performance, while 39% of projects with the higher Configuration Management capability exhibited Best Performance. Among the lower Performance projects, less consistent differences are seen elsewhere in Figure 55.

A *Gamma* value of 0.13 indicates that there is a weak positive relationship between Project Performance and the elements of Configuration Management addressed in this survey. A *p* value of 0.26 indicates that there is a 26% probability that a relationship of this magnitude could spontaneously occur by chance alone.

Note that the threshold for Lower Capability (3.0) is the highest in absolute terms among all composite capability scores analyzed. This, coupled with relatively even distribution across Project Performance categories and a weak positive Gamma relationship (0.13) with high p value, may indicate that Configuration Management practices are well accepted and implemented across projects (i.e., common-place and not a significant discriminator in Project Performance). This interpretation is supported by a high percentage of ‘Strongly Agree’ CM practices as depicted in Section D.3.12.

5.2.3.13 Overall Systems Engineering Capability versus Performance (SEC versus *Perf*)

The Overall Systems Engineering Capability (***SEC***) composite measure described in Section 5.1.3.13 showed a moderately strong positive statistical relationship with the Project Performance measure defined in Section 5.1.5.4, as shown in Figure 56.

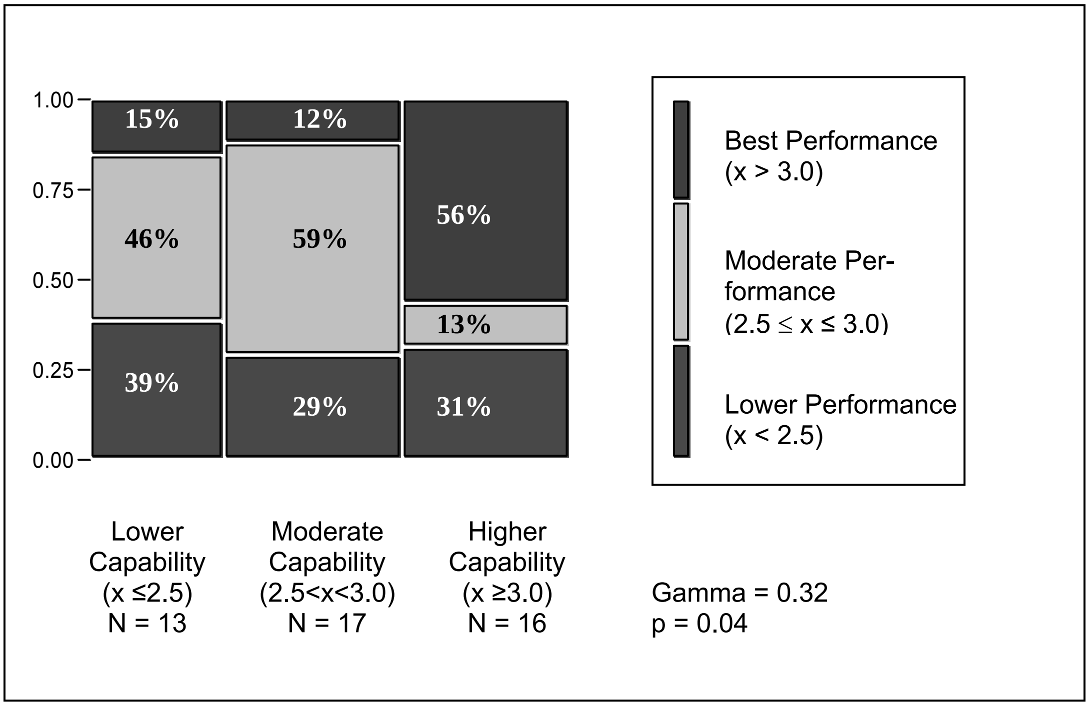


*Figure 56: Relationship Between Overall Systems Engineering Capability and Project Performance (**Perf** Versus **SEC**)*

Overall Systems Engineering Capability varied across the project sample with 13 projects exhibiting Lower Overall SE Capability, 17 exhibiting Moderate Overall SE Capability, and 16 exhibiting Higher Overall SE Capability. A moderately strong positive relationship between ***SEC*** and ***Perf*** is evident. Among projects exhibiting the Best Performance, only 15% of projects with lower Overall SE Capability exhibited Best Performance, while 56% of projects with higher Overall SE Capability exhibited Best Performance. The other differences in Figure 56 are less consistent and less pronounced.

The relationship between Overall Systems Engineering Capability and Project Performance succinctly summarizes the overall effect of the Systems Engineering practices covered in this survey. However, the relationship remains only moderately strong since the capability measure is based on all of the practices including those that appear to have a less direct effect on Project Performance.

A *Gamma* value of 0.32 indicates that there is a moderately strong positive relationship between Project Performance and the elements of Overall SE Capability addressed in this survey. A *p* value of 0.04 indicates that there is a 4% probability that a relationship of this magnitude could spontaneously occur by chance alone.

5.2.3.14 Combined Requirements and Technical Solution Capability versus Performance (SEC_{R+TS} versus Perf)

The moderately strong statistical relationships between Systems Engineering Capabilities and Project Performance just described are notable by themselves. However, selectively combining more than one of the composite capability measures that are most strongly related to Project Per-

formance can yield a notably stronger relationship. For example, we created a higher order SE Capability measure by combining the Requirements (***SEC_{REQ}***) and Technical Solution (***SEC_{TS}***) composite measures together into a single composite measure (***SEC_{R+TS}***) This was done simply by equally weighting the contribution of the original two composite scores.

Because of the small number of projects, we are unable to do rigorous multivariate statistical analyses of the combined effect of several measures on Project Performance (***Perf***). Instead we have created composite capability measures based on the statistical relationships between two or more other measures that themselves are related to Project Performance (***Perf***). As we have done throughout the report, the new combined measures are separated into three categories since a relatively small number of projects participated in the survey.

The Combined Requirements and Technical Solution Capability composite measure (***SEC_{R+TS}***)showed a strong positive statistical relationship with the Project Performance measure defined in Section 5.1.5.4, as shown in Figure 57

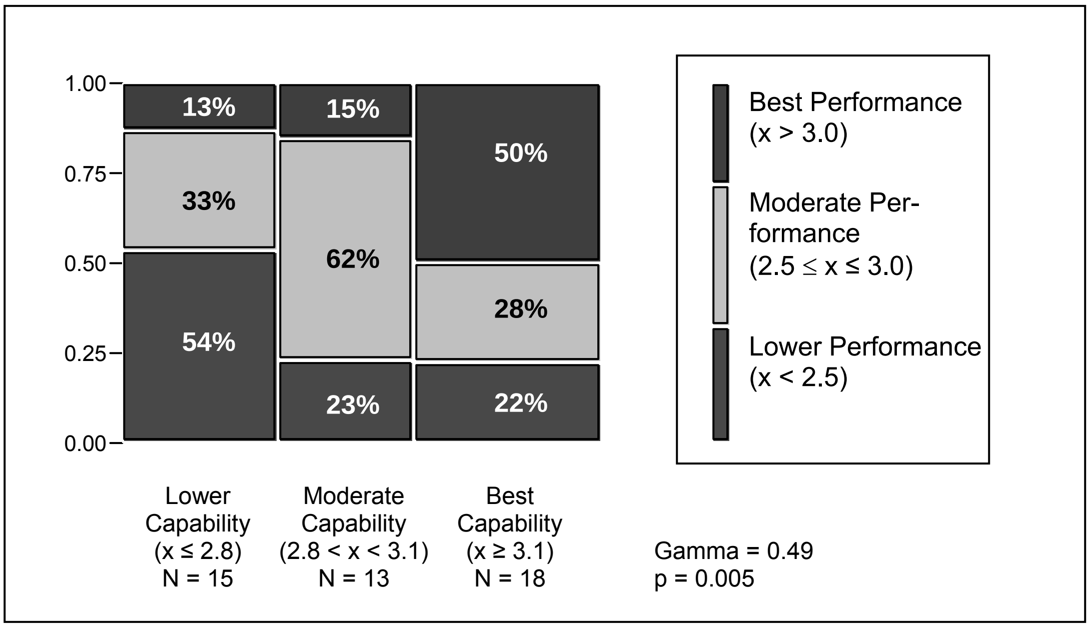


*Figure 57: Relationship between Combined Requirements and Technical Solution Capability and Project Performance (**Perf** Versus **SEC_{R+TS}**)*

Systems Engineering Capability varied across the survey sample with 15 projects exhibiting Lower Combined Requirements and Technical Solution Capability, 13 exhibiting Moderate Combined Requirements and Technical Solution Capability, and 18 exhibiting Higher Combined Requirements and Technical Solution Capability. Among projects exhibiting the Best Performance, only 13% of projects with Low capability exhibited Best Performance, while 50% of projects with High capability exhibited Best Performance. Lower Performance projects also showed similar differences, with 53% of projects with Lower Combined Requirements and Technical Solution Capability exhibiting Lower Performance, while only 22% of projects with Higher Combined Requirements and Technical Solution Capability exhibited Lower Performance.

A Gamma value of 0.49 indicates that there is a strong relationship between Project Performance and the elements of Requirements and Technical Solution deployment addressed in this survey. A *p* value of 0.005 indicates that there is a 0.5% probability that this type of relationship could occur by chance alone.

5.2.4 Relationships between Acquirer Capabilities (AC) and Performance (*Perf*)

The Acquirer Capability composite measure described in Section 5.1.4 showed a Moderately Strong negative relationship with the Project Performance composite measure defined in Section 5.1.5.4, as shown in Figure 58.

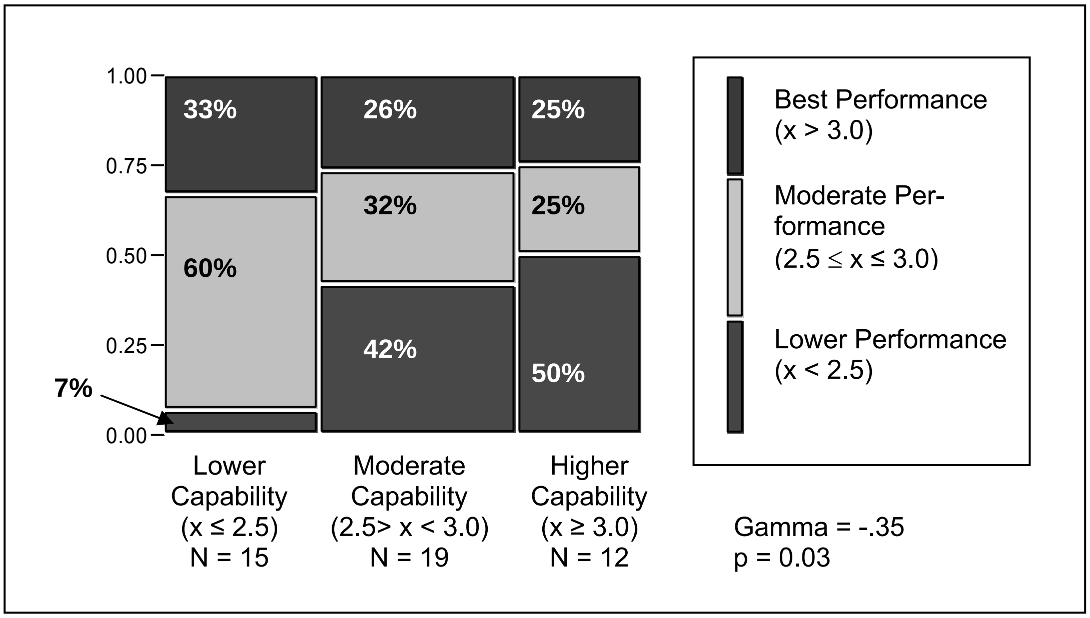


Figure 58: Relationship Between Acquirer Capability and Performance (***Perf*** *Versus* ***AC****)*

The Acquirer Capability was not obtained through surveying the acquirers, but was derived from information reported by the Suppliers. The indirect nature of the information may introduce additional biases and errors compromising the analysis.

Acquirer Capability varied across the project sample with 15 projects exhibiting low capability, 19 exhibiting moderate capability, and 12 exhibiting high capability. The projects with purportedly lower Acquirer Capability were somewhat more likely to exhibit Best Performance. However, what is most notable is the fact that the projects with Higher Acquirer Capability are much more likely to exhibit Lower Performance.

A *Gamma* value of -0.35 indicates that there is a moderately strong negative relationship between Project Performance and the elements of Acquirer Capability addressed in this survey. A *p* value of 0.03 indicates that there is a 3% probability that a relationship of this magnitude could spontaneously occur by chance alone

By themselves, these differences in Project Performance as a function of Acquirer Capability are puzzling, and no single cause for this phenomenon is obvious. However, bear in mind that Ac-

quirers were not polled in this survey; so direct insight into their capabilities was not possible. Rather, as noted in Section 5.1.4, the Acquirer Capability composite measure is derived from the suppliers' reports about

- the Acquirer's participation on Integrated Project Teams (IPTs)
- the Acquirer's provision of a Systems Engineering Plan (SEP)
- the Quality of system requirements
- the Completeness of system requirements
- the Stability of system requirements

Other things being equal, one would think that all of these factors would contribute to greater project success. The problem is that other things rarely are equal. Additional investigation clearly is needed to understand the reasons for this counter-intuitive finding.

For now, we can only make a few reasonably well informed conjectures. Our preliminary analyses based on these survey data are insufficient to present here. However, they do suggest that Acquirer Capability is fairly strongly associated with better SE Capability. That is, good acquirers are more likely to select good suppliers, but better Acquirer Capability appears to affect Project Performance indirectly. Acquirer Capability also does seem to have some mediating effects on the nature of the relationships between Project Performance and both Requirements and Technical Solution capabilities. However, the relationships are much less clear-cut than are those mediated by Project Challenge as shown in Section 5.3.1.

5.3 EFFECTS OF *PC*, *PE*, AND *AC* ON THE RELATIONSHIPS BETWEEN *SEC* AND *PERF*

In section 5.2.3, we have examined the relationships between Project Performance and 12 areas of SE Capabilities. From this we can form some opinions regarding the value of these SE practices. We can also ask additional questions of interest such as

- How is the impact of these SE practices upon Project Performance affected by the degree of challenge in the project?
- How is the impact of these SE practices upon Project Performance affected by the other factors in the project environment?
- How is the impact of these SE practices upon Project Performance affected by the acquirer's capabilities?

Unfortunately, our data do not allow us to examine the mediating effects of Project Environment factors or Acquirer Capabilities. The joint inter-relationships among them, the SE Capability measures and Project Performance simply are not sufficiently well distributed in the still relatively small sample for this survey. There are not enough projects in some categories and too many are concentrated in others. For example, Acquirer Capability tends to be higher when Project Challenge is lower. The relationship is a relatively weak one, but it confounds the analysis nonetheless.

However, the response distributions are sufficient to permit an examination of the mediating effects of Project Challenge on Project Performance

5.3.1 Moderating Effects of Project Challenge (*PC*)

To examine the effect of Project Challenge upon the relationships between SE Capabilities and Project Performance, we have chosen several of the SE Capability areas that show stronger influences on Project Performance. Within each of these areas, we have partitioned the data set into two subsets:

- those projects with higher Project Challenge
- those projects with lower Project Challenge

For each subset, as we did for the entire data set previously in Section 5.2, we then identify the relationship between the SE Capability area and Project Performance. The SE Capability areas chosen for this analysis are

• Total Systems Engineering Capability	versus	Performance	(***SEC*** versus ***Perf***)
• Combined Requirements and Technical Solution Capability	versus	Performance	(SEC_{R+TS} versus ***Perf***)

There is a good deal of consistency among the comparisons, despite the fact that the number of cases in each subset is low. Such consistency is unlikely to have occurred by chance alone. The p values are lower than those for the comparably strong bivariate relationships reported for the entire data set. However, that is because of the low numbers of cases in each subset when we make the same comparisons separately for the higher and lower challenge projects.

Since the number of cases is so small, one should be especially careful not to over interpret the percentage differences shown in the figures in this section. However, we do show the percentages to be consistent with the other results in this Special Report.

5.3.1.1 Effects of Project Challenge (*PC*) on the Relationship between Overall Systems Engineering Capability (*SEC*) and Project Performance (*Perf*)

The Overall Systems Engineering Capability (***SEC***) composite measure described in Section 5.1.3.13 is compared with the Project Performance (***Perf***) composite measure defined in Section 5.1.5.4 and controlled by the Project Challenge (***PC***) composite measure of Section 5.1.1. The results are shown in Figure 59.

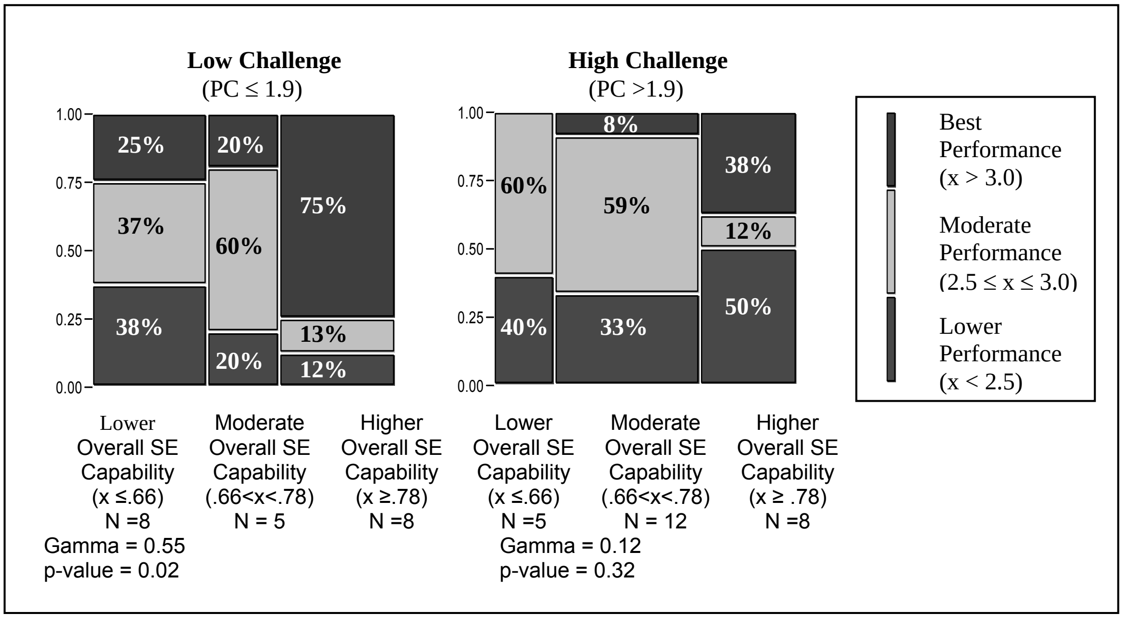


*Figure 59: Relationship Between Overall Systems Engineering Capability and Project Performance (**Perf** Versus **SEC**) controlled by Project Challenge (**PC**)*

The strength of the relationship between Overall SE Capability and Project Performance is evident for the Low Challenge projects. In this sample, of the eight projects with lower Overall SE Capabilities, 25% showed Best performance. As Overall SE Capabilities increased to moderate (five projects) to high (eight projects), achievement of Best Project Performance varied to 20% and 75%, respectively. Likewise, as Overall SE Capability increased from Low to Moderate to High, achievement of Lower Project Performance decreased from 38% to 20% to 12%, respectively.

A *Gamma* value of 0.55 for the Low Challenge projects indicates that there is a very strong positive relationship between Project Performance and the elements of Overall SE addressed in this survey. A *p* value of 0.02 indicates that there is a 2% probability that a relationship of this magnitude could spontaneously occur by chance alone.

A somewhat similar relationship may be seen for the High Challenge projects. In this sample, of the five projects with lower Overall SE Capabilities, none showed Best performance. As Overall SE Capabilities increased to moderate (twelve projects) and to high (eight projects), achievement of Best Project Performance increased to 8% and 38%, respectively. However, the differences in Lower Project Performance are not consistent. In fact, Lower Project Performance is most common (50%) among the projects that exhibit Higher Overall SE Capabilities. As noted earlier in Section 5.2.1, this may be due to the fact that the Overall SE Capabilities measure is based on all of the practices including those that appear to have less direct of an effect on Project Performance.

A *Gamma* value of 0.12 for the High Challenge projects indicates that there is a weak positive relationship between Project Performance and the elements of Overall Systems Engineering addressed in this survey. A *p* value of 0.32 indicates that there is a 32% probability that a relationship of this magnitude could spontaneously occur by chance alone.

The comparison of Low Challenge and High Challenge projects clearly shows that Systems Engineering Capability has a stronger influence on the Low Challenge projects (Gamma = 0.55 versus Gamma = 0.12). One possible interpretation of this is that the impact of the Higher Project Challenge on Project Performance marginalizes the impact of SE Capability.

Further interpretation of these relationships is explored in Section 5.3.1.3.

5.3.1.2 Effects of Project Challenge (*PC*) on the Relationship between Combined Requirements and Technical Solution Capability (SEC_{R+TS}) and Project Performance (*Perf*)

The Combined Requirements and Technical Solution Capability (***SEC_{R+T}***) measure described in Section 5.2.3.14 is compared with the Project Performance (***Perf***) composite measure defined in Section 5.1.5.4 and controlled by the Project Challenge (***PC***) composite measure of Section 5.1.1. The results are shown in Figure 60.

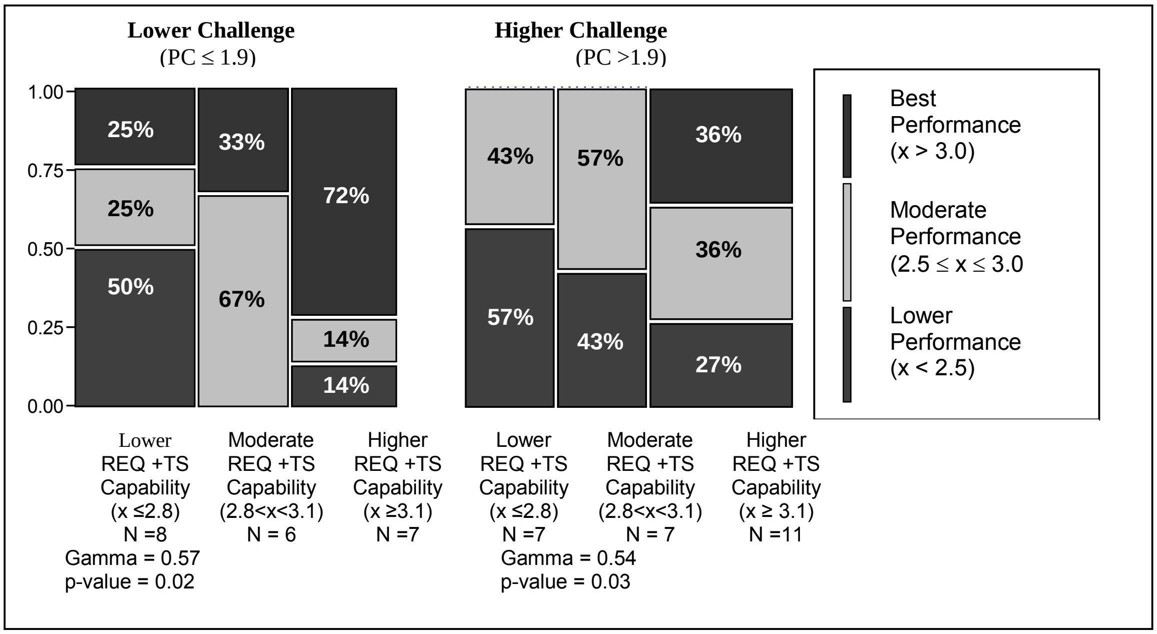


*Figure 60: Relationship Between Combined Requirements/Technical Solution Capability and Project Performance (**Perf** versus **SEC_{R+TS}**) controlled by Project Challenge (**PC**)*

The strength of the relationship between combined Requirements and Technical Solution capability and Project Performance is evident for the Low Challenge projects. In this sample, of the eight projects with lower combined Requirements and Technical Solution capabilities, 25% showed Best performance. As combined Requirements and Technical Solution capabilities increased through moderate (six projects) to high (seven projects), achievement of Best Project Performance rose to 33% and 72%, respectively. Likewise, 50% of the projects with Lower combined Requirements and Technical Solution capability achieved Lower Project Performance. In contrast, 14% of the high capability projects and none of the moderate capability projects exhibited Lower Project Performance.

A *Gamma* value of 0.57 for the Low Challenge projects indicates that there is a very strong positive relationship between Project Performance and the elements of Requirements and Technical

Solution addressed in this survey. A *p* value of 0.02 indicates that there is a 2% probability that this type of relationship could occur by chance alone.

A similar relationship may be seen among the High Challenge projects. None of the seven projects with lower combined Requirements and Technical Solution capabilities and none of the seven projects with moderate capabilities in this sample achieved Best performance. Yet, 36% of the 11 projects that exhibited high capability also did achieve Best Project Performance. Similarly, those who achieved only Lower Project Performance declined from 57% through 43% to 27% respectively.

A *Gamma* value of 0.54 for the High Challenge projects indicates that there is a very strong positive relationship between Project Performance and the elements of Requirements and Technical Solution addressed in this survey. A *p* value of 0.03 indicates that there is a 3% probability that this type of relationship could occur by chance alone.

The comparison of Low Challenge and High Challenge projects clearly shows that the combined Requirements and Technical Solution Capabilities have an equally strong influence on both the Low Challenge and High Challenge projects (Gamma = 0.57 versus Gamma = 0.54). Thus, improved capabilities in the areas of Requirements and Technical Solution appear to have a beneficial impact upon Project Performance, regardless of the degree of Project Challenge

Further interpretation of these relationships is explored in Section 5.3.1.3.

5.3.1.3 Summary of the Moderating Effects of Project Challenge

The impact of both Project Challenge and Overall SE Capability is apparent in the relationships explored in Sections 5.3.1.1 and 5.3.1.2. Details of this impact may be seen in the following observations:

- Referring to Figure 59, for the worst case scenario of lower Overall SE Capability and high Project Challenge, Project Performance results are discouraging, with
  - 0% of the projects reporting Best Performance,
  - 60% reporting Moderate Performance, and
  - 40% reporting Lower Performance.

  A similar result is seen in Figure 60. When lower Requirements and Technical Solution SE Capability are applied to more challenging projects,
  - 0% of the projects deliver Best Performance,
  - 43% deliver Moderate Performance, and
  - 57% deliver Lower Performance.

  This clearly shows the risk of asking less capable suppliers to perform on more challenging projects.

- Again referring to Figure 59, within the same group of projects presenting high Project Challenge, an improvement in the Overall SE Capability increases the number of projects reporting Best Performance from 0% to 38%. Likewise, from Figure 60 we see that improvement in Requirements and Technical Solution SE Capability increases the number of projects reporting Best Performance from 0% to 36%. This clearly shows the value of Overall SE Capability in addressing challenging projects.

- As seen in Figure 59, for high Project Challenge projects, a significant percentage of projects deliver Lower Performance (33 to 50%) regardless of the Overall SE Capability. For the low Project Challenge projects, the percentage of projects delivering Lower Performance ranges from 12 to 30% - a significant improvement. Similarly from Figure 60, for the high challenge projects the percentage of projects delivering Lower Performance ranges from 27 to 57%. For less challenging projects, this range drops to 14 to 50%. This clearly shows the impact of Project Challenge on Project Performance, and suggests that improving Overall SE Capability is not enough; Project Challenge must also be managed.

- Once again from Figure 59, for the best case scenario of Higher Overall SE Capability and low Project Challenge, Project Performance results are very favorable, with 75% of less challenging projects reporting Best Performance and only 12% reporting Lower Performance. Likewise from Figure 60, 72% of less challenging projects reported Best Performance and only 14% reported Lower Performance. This illustrates the ideal situation that is attainable through improvement of SE Capabilities and reduction and management of Project Challenge.

As noted previously, we were unable to do rigorous multivariate statistical analyses of the combined effect of several measures on Project Performance (***Perf***) because of the small number of project responses. Instead we have created a new overall measure by using the statistical relationships between the Combined Requirements and Technical Solution Capability (SEC_{R+TS}) measure described in Section 5.2.3.14 and the Project Challenge (***PC***) measure described in Section 5.1.1. As usual, three categories were used since a relatively small number of projects participated in the survey. Scoring was as follows:[7]

- Projects that exhibited both <u>higher</u> SEC_{R+TS} capability and <u>lower</u> ***PC*** challenge were categorized in Figure 61 as “Higher Capability and Lower Challenge”. So too were projects that scored in one of those same two categories along with the middle category on the other.
- Similarly, projects that exhibited both <u>lower</u> SEC_{R+TS} capability and <u>higher</u> ***PC*** challenge were categorized in Figure 61 as “Lower Capability and Higher Challenge”. So too were projects that scored in one of those same two categories along with the middle category on the other.
- Projects that exhibited both moderate capability and moderate challenge were categorized as “Mixed Capability and Challenge”. So too were projects that exhibited both <u>lower</u> SEC_{R+TS} capability and <u>lower</u> ***PC*** challenge, as were those that exhibited both <u>higher</u> SEC_{R+TS} capability and <u>higher</u> ***PC*** challenge.

This categorization is illustrated in Table 5.

[7] The cutting points for ***PC*** were changed somewhat to create a better balanced joint distribution for the new higher order SEC_{R+TS}+***PC*** composite measure. The adjusted cutting points for ***PC*** are 1.76 and 2.04.

Table 5: SE Capability and Project Challenge Categorization

		SEC_{R+TS} Capability		
		Lower	Moderate	Higher
Project Challenge	Higher	**Lower Capability and Higher**		**& Capability**
	Moderate	**Challenge**	**Challenge**	**Higher**
	Lower	**Mixed**	**Capability & Lower Challenge**	

This Combined Requirements/Technical Solution Capability and Project Challenge (**SEC_{R+TS}+PC**) measure was compared with the Project Performance (***Perf***) composite measure defined in Section 5.1.5.4. The results are shown in Figure 61.

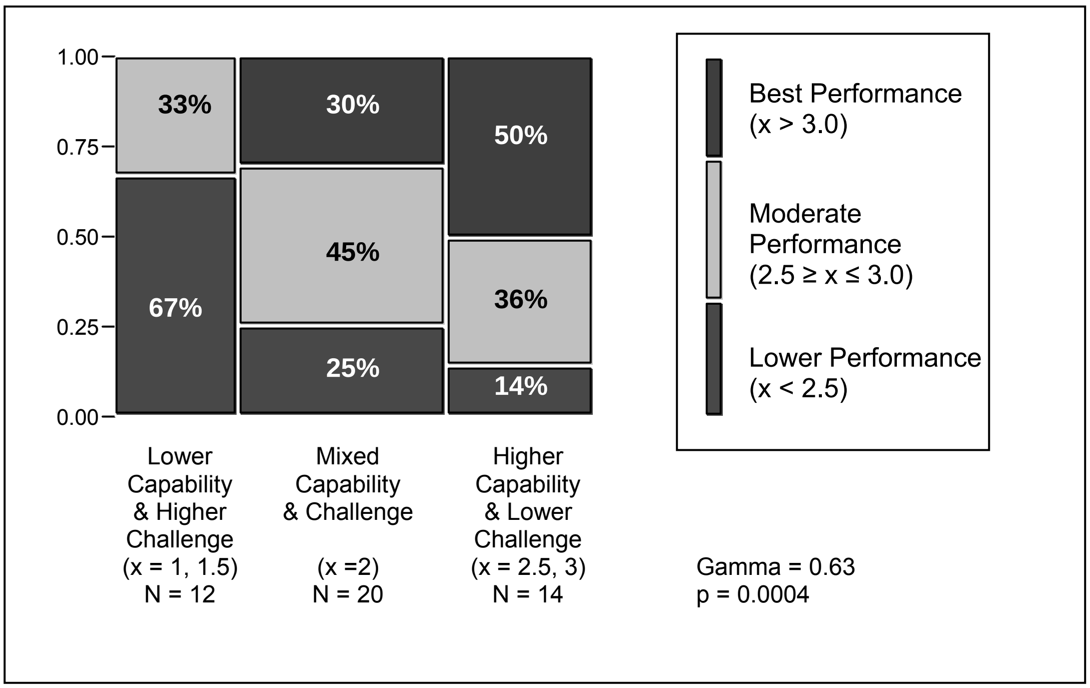


*Figure 61: Relationship Between Combined Requirements/Technical Solution Capability and Project Challenge on Project Performance (**Perf** Versus **SEC_{R+TS}+PC**)*

The overall effects of Systems Engineering Capability combined with Project Challenge varied across the survey sample with 12 projects exhibiting Lower Capability and Higher Challenge, 20 exhibiting Mixed Capability and Challenge, and 14 exhibiting Higher Capability and Lower Challenge. A very strong 0.63 positive relationship between ***SE_{CR+TS}+PC*** and ***Perf*** is evident. Half (50%) of the projects that exhibited Higher Capability and faced lower Project Challenge achieved Best Performance. However, none of the projects that exhibited Lower Capability and faced Higher Challenge managed to achieve Best Performance. Similarly, 67% of the projects with Lower Capability and Higher Challenge managed only to achieve Lower Performance. Only 14% of projects with Higher Capability and Lower Challenge exhibited Lower Performance.

A *Gamma* value of 0.63 indicates that there is a very strong relationship between Project Performance and the aspects of Systems Engineering Capability combined with Project Challenge addressed in this survey. A p value of 0.0004 indicates that there is an extremely low probability that this type of relationship could occur by chance alone.

An alternative way to visualize these relationships is shown in Figure 62 and Figure 63. In Figure 60, the two graphs contain six columns, each with percentages of projects exhibiting Best, Moderate, and Lower Project Performance. For each column, we can calculate a performance score through the weighted combination of these three percentages. This score is calculated as:

Score = ½ x [0 x (% of Lower Performance projects) +
1 x (% of Moderate Performance Projects) +
2 x (% of Best Performance Projects)]

This score gives a weight of 2 to projects exhibiting Best Performance, a weight of 1 to projects exhibiting Moderate Performance, and a weight of 0 to projects exhibiting Lower Performance. The factor of ½ included in the formula normalizes the score to range from 0 (i.e. 100% of the projects exhibit Lower Performance) to 1 (i.e., 100% of the projects exhibit Best Performance).

Figure 62 and Figure 63 illustrate this score as a function of Project Challenge and SE Capabilities.

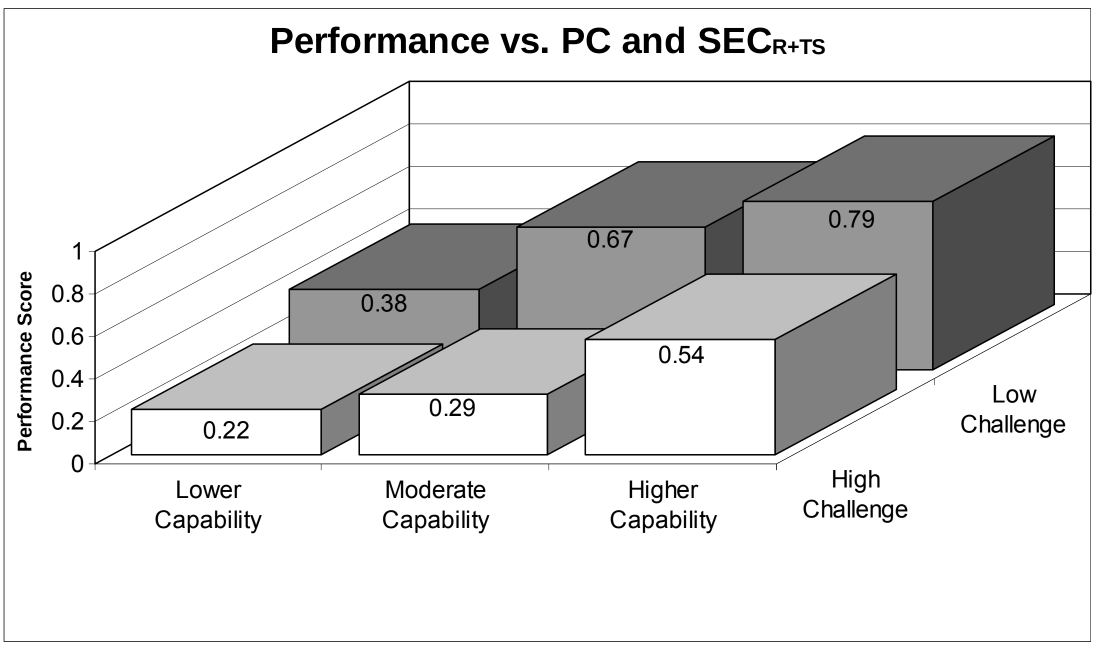


Figure 62: Performance vs. Project Challenge and Requirements + Technical Solution SE Capability

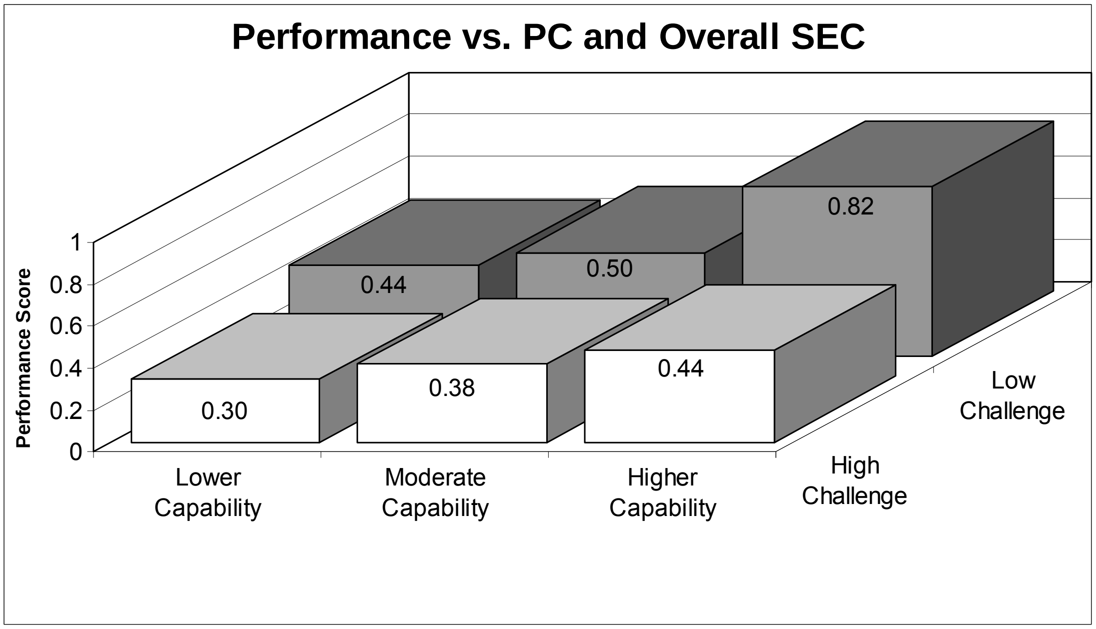


Figure 63: Performance vs. Project Challenge and Overall SE Capability

Both figures clearly show the combined impacts of Project Challenge and SE Capability.

6 Limitations and Lessons Learned

Development and execution of this survey was a complex effort. Complex efforts produce challenges. Challenges produce learning. Some of the lessons learned from this activity follow.

1. **The lack of a widely accepted definition of Systems Engineering need not be an obstacle to identifying SE activities deployed on projects.**
   The debate over the definition of Systems Engineering has raged for decades, without resolution. Even today, there is no widely accepted definition. How do you survey a capability if you cannot define that capability? This question had thwarted previous attempts of the SEEC to identify the value of SE. This survey avoided that obstacle. Rather than enter the debate as to what does or does not constitute SE, this survey examined specific activities and practices that were likely to be considered as elements of SE by most systems engineers. Decisions as to what to include in the survey and what to omit were made by a panel of experienced systems engineers.

2. **Indirect access to respondents helped protect confidentiality of respondent's data, but made it more difficult to track progress and to analyze data**
   The questionnaire requested a great amount of information about the methods deployed on a project (i.e., the Systems Engineering activities applied to the project) and the results achieved by the project (i.e., the Project Performance). Exposure of this information to competitors and/or customers could be disadvantageous to the responding project or organization, exposing operational details in a competitive environment. For this reason, the SEEC made a decision early in the development of the survey that respondent's data must be securely handled. This decision drove a number of subsequent decisions:

   a. The SEI was chosen as a trusted agent to collect, analyze, and report the survey results.

   b. The questionnaire was constructed to collect no information that could expose the identity of the respondent, the project, or the organization.

   c. The survey execution was done via the Web, enabling the collection of responses in an anonymous manner.

   d. Respondents were solicited via proxy, using "focal contacts" within targeted organizations to identify, solicit, and expedite respondents within that organization.

   Of these decisions, the last proved to be the most problematic. The use of proxies isolated the survey execution team from the respondents, as it was intended to do. However, this meant that the survey execution was largely dependent on the efforts of the proxies. These proxies were asked to

   – identify candidate respondents
   – solicit the participation of the respondents
   – report the number of respondents solicited to the SEI

- expedite respondents at defined times, and report the number of responses submitted to the SEI

The first challenge encountered by the SEEC was the identification of appropriate and willing proxies. The SEEC initially attempted a top-down approach, contacting candidate proxies at the highest levels of the organization, and asking them to propagate the survey throughout the organization. This approach was only partially successful. In some cases, the candidate proxies were not aware of or aligned with the mission of the SEEC and NDIA in general. The SEEC was unable to convince them of the value of this survey. In some cases, these candidate proxies were just too busy to address this request. For cases where the SEEC was unsuccessful at penetrating an organization at the top level, we resorted to lower levels—rather than work through corporate headquarters, we attempted to contact proxies at the divisional level. This again was only partially successful. Again, in some cases, the candidate proxies were not aware of or aligned with the mission of the SEEC and NDIA in general. The SEEC was unable to convince them of the value of this survey. In some cases, again, these candidate proxies were just too busy to address this request. In yet other cases, the candidate proxies were unwilling to proceed without corporate approval.

Once the proper proxies were found, the SEEC then became dependent on their efforts to execute the survey. While the SEEC carefully crafted instructions and solicitation aids for the proxies (see APPENDIX C), the initiative to identify and solicit respondents fell wholly to the proxies. While many did a fine job, others did not. Due to the anonymous nature of the survey responses, the SEEC has no way of knowing who did or did not respond. However, we do know that many of the proxies failed to provide the oft-requested response rate data; thereby implying little or no response.

The use of proxies was intended to increase the response rate by

a. enhancing the anonymity of the respondents
b. enhancing the credibility of the survey effort within the responding organization by having the solicitation of respondents done by insiders

While the use of proxies may have aided in the achievement of these goals, success was compromised by the challenge of the indirect contact between the researchers and the respondents. The results were fewer responses than desired. We had hoped for at least 200 responses; we received 64. This limited our ability to do more detailed statistical analyses of several important topics. Equally importantly, we were not able to generalize some of our findings more widely because the sample was not based explicitly on known probabilities of selection [Foreman 1991]. Although it is impossible to know whether the number of responses would have increased with an alternate solicitation method, this is a topic for further consideration in future surveys.

3. **Piloting by the SEEC did not fully expose question interpretation issues**
As noted in Section 3.1, the survey execution methods and the survey questionnaire were tested in a pilot phase. The questionnaire was distributed to a small number of members of the SEEC, who were requested to respond using the web site developed for the survey. This activity provided a number of useful outcomes:

a. It revealed that the survey was too long. Initial times to complete the questionnaire ranged from 30 minutes to 3 hours.

b. It exposed a number of issues with the Web-based data collection process.

As a result of this piloting, the questionnaire was substantially reduced and simplified, reducing the average completion time to about 40 minutes. The issues with the Web-based collection process were also addressed.

In retrospect, it appears that the piloting, while helpful, was not sufficient to expose additional weaknesses in the questionnaire. Only after the responses were received did it become apparent that a few of the questions were not as clearly stated as they needed to be. This was evident from the unreasonably wide range of responses to some questions, and from inconsistencies with these responses and responses to other questions in the survey. These issues only affected a few questions within the survey. As a result, the responses to these questions were not used in the overall analysis.

Two reasons are postulated for the inability of the pilot effort to recognize these weaknesses.

a. The number of respondents involved in the piloting was too small.

b. The pilot respondents may not have been representative of the survey population. The pilot respondents were self-selected from the members of the SEEC. As such, they were perhaps more knowledgeable about Systems Engineering than the average respondent. Additionally, they may have been more motivated than the average respondent.

4. **Insufficient attention to the adequacy of survey sampling analysis methods during survey development**

   Prior to the development of the survey, the survey main hypothesis (i.e., effective performance of Systems Engineering best practices results in quantifiable improvement in program execution) was defined (see Section 1.3). The questionnaire was crafted to test this hypothesis. Similarly, the other survey questions were crafted to allow us to test more detailed hypotheses about the mediating effects of other pertinent factors that might affect both the use of SE best practices and Project Performance under varying conditions. However a number of uncertainties remained unresolved throughout the development of the survey. In particular, we were unsure about the number and types of responses that would be received. Responses could have come from $50,000 sub contract efforts or billion dollar programs. While the data analysis methods to be used on the responses were known, we were reluctant to commit to a firm analysis plan until some of this uncertainty was resolved.

   As is common in exploratory data analysis, a detailed analysis plan was not formed until after the responses were received. The analysis was then performed iteratively [Tukey 1977]. As noted previously, fewer responses were received than hoped for. Also, the sizes and kinds of responding projects varied over a large range. These factors did indeed influence the analysis plan, with the smaller-than-desired number of responses limiting the number and kinds of analyses that could be performed.

   Nevertheless, the development of a more detailed analysis plan prior to the deployment of the questionnaire would have been helpful. In completing the analysis plan, several instances

were encountered where additional information would have been useful in understanding the project's responses. Had these needs been determined prior to deployment, the questionnaire could have been modified to collect the needed data.

5. **Insufficient stakeholder involvement limited response to the survey**
   Throughout the development and execution of this survey, the SEEC made significant efforts to involve all stakeholders. All SEEC meetings were open to all members of the NDIA SED. Anyone who attended a meeting was considered a committee member and was placed on the committee email list—a list that grew to 54 names. Weekly or biweekly telephone conferences were held. Status reports were presented at SED meetings. In spite of these efforts, involvement of some stakeholders remained insufficient. Future efforts need to ensure closer coordination to ensure continued stakeholder involvement.

7 Summary

The impetus for this survey was a desire to answer the questions:

1. What will the application of Systems Engineering practices cost me?
2. What benefits will I gain from the application of these practices?

An understanding of these answers is needed to justify a project's investment in SE resources and activities. To address these questions, we assessed the impact of the deployment of SE practices on Project Performance. Knowing that SE was not the only factor influencing Project Performance, we also assessed Project Challenge, Project Environment factors, and Acquirer Capability to identify their relationship to Project Performance. The analysis of the collected data shows that there are indeed identifiable relationships between many of these driving factors and Project Performance. Ranked by the strength of association with Project Performance, these driving factors are shown in Table 6.

Table 6: Ranked Project Performance Driving Factors

Driving Factor[8]	**Type**	**Relationship to Project Performance**		**Section Reference**
		Description	**(Gamma**[9]**)**	
Requirements and Technical Solution Combined with Project Challenge	SEC +PC	Very strong positive	+0.63	5.3.1.3
Combined Requirements and Technical Solution	SEC	Strong positive	+0.49	5.2.3.14
Product Architecture	SEC	Moderately strong to strong positive	+0.40	5.1.3.7
Trade Studies	SEC	Moderately strong to strong positive	+0.37	5.1.3.6
IPT-Related Capability	SEC	Moderately strong positive	+0.34	5.1.3.1
Technical Solution	SEC	Moderately strong positive	+0.36	5.1.3.8
Requirements Development and Management	SEC	Moderately strong positive	+0.33	5.1.3.5
Overall Systems Engineering Capability	SEC	Moderately strong positive	+0.32	5.1.3.13

8 Use caution in to avoid over-interpreting the meaning of the Systems Engineering Capability (SEC) categories, Project Challenge, and Project Environment Factors listed in Table 6. For example, the "Project Planning" category does include elements of project planning, but is not a comprehensive compilation of all project planning activities. To properly understand the listed relationships, please refer to the report sections listed in the last column to see what survey questions are included in the SEC category.

9 Gamma is a measure of association that expresses the strength of relationship between two ordinal variables, with values near -1 indicating a strong opposing relationship, values near 0 indicating a weak or no relationship (statistical independence), and values near +1 indicating a strong supporting relationship

Table 6: Ranked Project Performance Driving Factors

Driving Factor[8]	Type	Relationship to Project Performance		Section Reference
		Description	(Gamma[9])	
Project Challenge	PC	Moderately strong negative	-0.31	5.1.1
Validation	SEC	Moderately strong positive	+0.28	5.1.3.11
Risk Management	SEC	Moderately strong positive	+0.28	5.1.3.4
Verification	SEC	Moderately strong positive	+0.25	5.1.3.10
Product Integration	SEC	Weak positive	+0.21	5.1.3.9
Project Planning	SEC	Weak positive	+0.13	5.1.3.2
Configuration Management	SEC	Weak positive	+0.13	5.1.3.12
Process Improvement	PE	Weak positive	+0.05	5.1.2.3
Project Monitoring and Control	SEC	Weak negative	-0.13	5.1.3.3

The survey also examined Project Environment factors that may or may not influence Project Performance. Due to the relatively small sample size and the small number of respondents, the number of projects in each answer category for the Project Environment questions were sufficiently small to reduce the confidence one can have in these findings. Results are presented in this report, but care should be taken not to over interpret these differences.

Finally, the survey examined the impact of the Acquirer's capabilities upon Project Performance. Although the survey was not specifically designed to provide a detailed assessment of the acquirer's capabilities, some responses from the suppliers could be used to develop a rudimentary relative measure of some acquirer capabilities. Due to the narrow scope of the acquirer assessment, and the indirect nature of this assessment (i.e., assessment of acquirers via suppliers), the relationships between Acquirer Capability and Project Performance are unclear.

The moderately strong statistical relationships between Systems Engineering Capabilities and Project Performance summarized here are notable by themselves. Other things being equal, better Systems Engineering Capabilities do tend to lead to better Project Performance. Of course, Systems Engineering Capability alone does not ensure outstanding Project Performance. The survey results also show notable differences in the relationship between SE best practices and performance among more challenging as compared to less challenging projects (section 5.3.1).

Table 7 provides a summary of the relationships analyzed in Section 5.2. Each row of the table shows a parameter (e.g., Project Challenge, an SE Capability) whose relationship to Project Performance was analyzed in Section5.2. The columns of the table show:

- the break points defining the Lower, Moderate, and Higher categories of each parameter.
- the percentage of Lower Performance, Moderate Performance, and Best Performance projects contained within each category
- the 'Gamma' (Γ) and 'p' statistics calculated for each relationship.

Table 7: Summary of Relationship Data

	Lower Category					Moderate Category					Higher Category						
	Min. Range	% Low Perf	% Mod Perf	% Best Perf	Max. Range	Min. Range	% Low Perf	% Mod Perf	% Best Perf	Max. Range	Min. Range	% Low Perf	% Mod Perf	% Best Perf	Max. Range	Γ	p
Project Challenge																	
PC	1.0	22%	28%	50%	1.85	1.85	42%	58%	0%	2.05	2.05	38%	38%	25%	4.0	-31%	5.0%
Project Environment																	
CMMI	1.0	36%	57%	7%	1.95	1.95	29%	36%	35%	2.7	2.7	33%	28%	39%	4.0	22%	13.0%
IMP	1.0	25%	55%	20%	2.17	2.17	42%	29%	29%	2.84	2.84	33%	25%	42%	4.0	5%	39.0%
EXP	1.0	29%	42%	29%	2.5	2.5	39%	44%	17%	3.5	3.5	29%	29%	42%	4.0	9%	33.0%
Systems Engineering Capability																	
IPT	1.0	33%	54%	13%	2.5	2.5	43%	38%	19%	3.1	3.1	20%	27%	53%	4.0	34%	4.0%
PP	1.0	33%	54%	13%	2.8	2.8	29%	35%	36%	3.3	3.3	35%	29%	36%	4.0	13%	25.0%
PMC	1.0	23%	54%	23%	2.5	2.5	23%	46%	31%	3.0	3.0	45%	25%	30%	4.0	-13%	25.0%
RSKM	1.0	35%	47%	18%	2.8	2.8	27%	66%	7%	3.6	3.6	36%	0%	64%	4.0	28%	6.1%
REQ	1.0	44%	38%	18%	2.8	2.8	26%	53%	21%	3.4	3.4	27%	18%	55%	4.0	33%	4.0%
TRADE	1.0	39%	44%	17%	2.7	2.7	42%	41%	17%	3.3	3.3	19%	32%	49%	4.0	37%	3.0%
ARCH	1.0	45%	44%	11%	2.7	2.7	29%	42%	29%	3.3	3.3	23%	31%	46%	4.0	40%	0.2%
TS	1.0	40%	53%	7%	2.8	2.8	33%	40%	27%	3.2	3.2	27%	27%	46%	4.0	36%	3.0%
PI	1.0	36%	54%	14%	1.5	1.5	33%	38%	29%	3.5	3.5	29%	29%	42%	4.0	21%	16.0%
VER	1.0	31%	62%	7%	2.7	2.7	33%	34%	33%	3.2	3.2	33%	20%	47%	4.0	25%	9.0%
VAL	1.0	54%	23%	23%	2.7	2.7	17%	66%	17%	3.3	3.3	29%	33%	38%	4.0	28%	7.0%
CM	1.0	29%	47%	24%	3.0	3.0	46%	36%	18%	3.67	3.67	28%	33%	39%	4.0	13%	26.0%
Overall SEC	1.0	39%	46%	15%	2.5	2.5	29%	59%	12%	3.0	3.0	31%	13%	56%	4.0	32%	4.0%
REQ+TS	1.0	43%	50%	13%	2.8	2.8	23%	62%	15%	3.1	3.1	22%	28%	50%	4.0	49%	0.5%
Acquirer Capability																	
AC	1.0	7%	60%	33%	2.5	2.5	41%	32%	26%	3.0	3.0	50%	25%	25%	4.0	-35%	3.0%

In summary, both Systems Engineering and Project Challenge must be considered together in explaining variation in Project Performance. Just as higher Systems Engineering Capability is associated with better Project Performance, higher Project Challenge is associated with lower Project Performance. It is the combination of capability and challenge that better explains the variation in performance than does either one alone. This is illustrated in Figure 64.

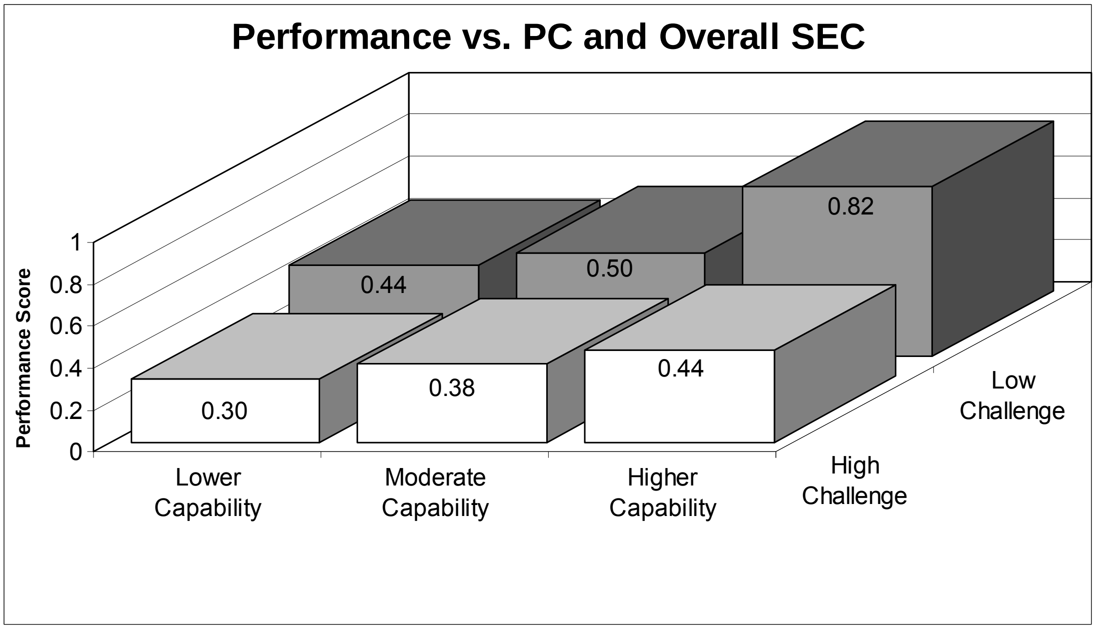


Figure 64: Performance vs. Project Challenge and Overall SE Capability

As shown in this report, improving Systems Engineering capabilities clearly can result in better Project Performance. However, more consideration also must be paid to ways of reducing Project Challenge. Doing so is a major challenge prior to the establishment of the development project, beginning during the pre-acquisition period. Earlier application of Systems Engineering practices and principles may go a long way towards reducing that challenge.

The relationships presented herein may be used in a number of ways:

- Defense contractors can use this report to plan capability improvement efforts for their SE programs. By focusing improvement resources on those SE activities most strongly associated with improved Project Performance, management may optimize the efficiency and effectiveness of those improvement efforts.
- Defense contractors can compare their organization's SE performance against the industry benchmark established by this survey. Projects within the organization can complete the survey questionnaire. Their responses can then be compared against the aggregated survey responses question-by-question to get a measurement of the project's SE Capability relative to the survey population. This benchmarking process can be periodically repeated to track the impact of SE improvement efforts

  Note that the question-by-question responses are contained in APPENDIX D. As promised,

the survey participants will have access to this information upon the limited publication and distribution of this report. Others will not have access to this data until the report is publicly released one year later.

- Systems Engineers and SE managers at defense contractors can use this report as justification for and in defense of their SE estimates.
- Acquisition PMOs may use this report to plan contractor evaluations during RFP development and source selection. Since this survey shows clear statistical relationships between specific SE Capabilities and improved Project Performance, acquirers can structure RFPs and source selection activities to include evaluation and consideration of these capabilities; thereby increasing the likelihood of project success.
- Throughout the execution of a project, acquisition PMOs may employ this survey or similar methods to collect data from suppliers as a means of identifying supplier deficiencies contributing to project risks.
- OSD may use this survey as guidance to Project Managers conveying the value of SE. This knowledge can assist the PMs in prioritizing resources and evaluating supplier budgets.

8 Next Steps

This report shows a clear relationship between the deployment of SE practices and improved Project Performance. While the output of this survey activity is complete in its current form, and needs no further work to find application in the defense industry today, it also suggests some directions for future initiatives.

8.1 CORRELATE REPORT FINDINGS WITH OTHER SOURCES

While numerous other initiatives have been undertaken within government, industry, and academia to characterize the best SE practices (or lack thereof) applied on defense programs, the benefit of this report is to support informed decision-making based on both quantitative and qualitative measures of effectiveness. This data can be used to complement findings derived from other sources, such as studies, reports, or root cause analyses of program performance issues, to develop a well-rounded picture of the state-of-the-practice for SE within the defense industry and to prioritize improvement actions in areas that are likely to have the greatest benefit in improved program performance.

8.2 DEVELOP IMPROVEMENT RECOMMENDATIONS

Based on the findings of this report, the NDIA Systems Engineering Effectiveness Committee (SEEC) will develop recommendations for government and industry actions needed to improve the practice of systems engineering on DoD programs.

Candidate areas for these recommendations may include, but are not limited to

- updates to OSD policy and guidance to reinforce the application and support of sound systems engineering practices on programs
- improved training in targeted SE capability areas (significant strengths or weaknesses)
- recommendations on standard measures to be collected and analyzed
- suggested improvement to evaluation criteria for program plans, reviews, or risk analyses
- greater communication of proven SE best practices (e.g., publications, conferences, workshops)

Note that numerous other efforts are already underway to improve systems engineering capabilities across the defense industrial base. For example, in the Office of the Deputy Under Secretary of Defense (A&T), the Director, Systems and Software Engineering has established a number of initiatives focusing on SE [Schaeffer 2007]. These include

- issuing a Department-wide Systems Engineering (SE) policy
- issuing guidance on SE, T&E, and SE Plans (SEPs)
- integrating DT&E with SE policy and assessment functions—focusing on effective, early engagement of both

- working with Defense Acquisition University to revise curricula (SPRDE, T&E, PQM, LOG, PM, ACQ, FM, CONT)
- establishing the SE Forum to ensure senior-level focus within DoD
- leveraging close working relationships with industry and academia
- instituting system-level assessments in support of DAB, OIPT, DAES, and in support of programs
- instituting a renewed emphasis on modeling and simulation in acquisition

To maximize the likelihood of positive action, recommendations developed by the SEEC will give utmost consideration to leveraging existing initiatives such as these, where there is already considerable inertia and government/industry support for improvement activities, before proposing new initiatives that would otherwise be competing for attention and resources.

8.3 ADDITIONAL ANALYSIS OF COLLECTED DATA

The analysis discussed in this report does not extract *all* of the knowledge available from the collected data set; additional analysis is possible. Many areas of study are possible; two examples are presented below.

For example, responding projects were executing in various phases across the life cycle. While data on Project Performance was collected, it was not compared with position in the life cycle. Early in a project, estimates of cost-at-completion and project completion dates seldom vary from original estimates. Only as progress (or lack of progress) occurs are deviations from these original estimates recognized. Thus, on-budget and on-schedule claims later in a project are more credible than the same claims early in the project. This factor could be included in a more sophisticated analysis of Project Performance.

As another example, the survey collects data on organizational CMMI maturity levels. Achievement of these levels requires the achievement of specified CMMI goals, and includes the expectation of performance of various CMMI practices. Many of the survey questions assessing SE Capabilities are related to these same practices. An analysis of the consistency between the claimed maturity levels and the performance of practices could reveal the degree of deployment of CMMI from the organizational level to the project level.

8.4 PERIODIC REPEAT OF THE SURVEY

Broader representation of programs and companies across the defense industrial base could help provide additional insight beyond this initial survey analysis. As government- and industry-based initiatives prevail, one could also expect to see improvements in SE Capabilities applied to projects.

Meanwhile, defense systems continue to reach unprecedented levels of complexity in a dynamic environment that is continually evolving in areas such as program mission, emerging technologies, development approaches, tools, teaming relationships, and acquisition strategies.

A periodic re-execution of this survey and similar subsequent efforts could quantify the improvements in SE Capability, and could also ascertain the impact of these changes on Project Performance.

8.5 SURVEY OF ACQUIRERS

Everything in this survey is presented from the perspective of the supplier. Additional knowledge could be gained by examining projects from the perspective of the acquirer. This could be accomplished through the development of a similar, but not identical, questionnaire. While it would be valuable to be able to join the results of the current survey with such an acquirer survey, this most probably will not be feasible due to the anonymous nature of the current survey data. Addressing both perspectives together while maintaining confidence in nondisclosure is an important challenge for future work in this area..

APPENDIX A Analysis of CMMI to Identify and Select SE-related Work Products

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Organizational Process Focus					
SG 1: Determine Process-Improvement Opportunities - Strengths, weaknesses, and improvement opportunities for the organization's processes are identified periodically and as needed.	SP 1.1-1: Establish Organizational Process Needs - Establish and maintain the description of the process needs and objectives for the organization.	Organization’s process needs and objectives			
	SP 1.2-1: Appraise the Organization’s Processes - Appraise the processes of the organization periodically and as needed to maintain an understanding of their strengths and weaknesses.	Plans for the organization's process appraisals			
		Appraisal findings that address strengths and weaknesses of the organization's processes			
		Improvement recommendations for the organization's processes			
	SP 1.3-1: Identify the Organization's Process Improvements - Identify improvements to the organization's processes and process assets.	Analysis of candidate process improvements			
		Identification of improvements for the organization's processes			
SG 2: Plan and Implement Process-Improvement Activities - Improvements are planned and implemented, organizational process assets are deployed, and process-related experiences are incorporated into the organizational process assets.	SP 2.1-1: Establish Process Action Plans - Establish and maintain process action plans to address improvements to the organization's processes and process assets.	Organization's approved process action plans			
	SP 2.2-1: Implement Process Action Plans - Implement process action plans across the organization.	Commitments among the various process action teams			
		Status and results of implementing process action plans			
		Plans for pilots			
	SP 2.3-1: Deploy Organizational Process Assets - Deploy organizational process assets across the organization.	Plans for deploying the organizational process assets and changes to organizational process assets			
		Training materials for deploying the organizational process assets and changes to organizational process assets			
		Documentation of changes to the organizational process assets			
		Support materials for deploying the organizational process assets and changes to organizational process assets			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 2.4-1: Incorporate Process-Related Experiences into the Organizational Process Assets - Incorporate process-related work products, measures, and improvement information derived from planning and performing the process into the organizational process assets.				
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an	GP 5.1: Ensure Continuous Process Improvement				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Optimizing Process	GP 5.2: Correct Root Causes of Problem				
Organizational Process Definition					
SG 1: Establish Organizational Process Assets - A set of organizational process assets is established and maintained.	SP 1.1-1: Establish Standard Processes - Establish and maintain the organization's set of standard processes.	Organization's set of standard processes	Y	Y	*PD01*
	SP 1.2-1: Establish Life-Cycle Model Descriptions - Establish and maintain descriptions of the life-cycle models approved for use in the organization.	Descriptions of life-cycle models			
	SP 1.3-1: Establish Tailoring Criteria and Guidelines - Establish and maintain the tailoring criteria and guidelines for the organization's set of standard processes.	Tailoring guidelines for the organization's set of standard processes			
	SP 1.4-1: Establish the Organization’s Measurement Repository - Establish and maintain the organization’s measurement repository.	Definition of the common set of product and process measures for the organization's set of standard processes			
		Design of the organization’s measurement repository			
		Organization's measurement repository (i.e., the repository structure and support environment)			
		Organization’s measurement data			
	SP 1.5-1: Establish the Organization’s Process Asset Library - Establish and maintain the organization's process asset library.	Design of the organization’s process asset library			
		Organization's process asset library			
		Selected items to be included in the organization’s process asset library			
		Catalog of items in the organization’s process asset library			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a	GP 2.1: Establish an Organizational Policy				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Managed Process	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stake-holders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Organizational Training					
SG 1: Establish an Or-ganizational Training Capability - A training capability that supports the organization's man-	SP 1.1-1: Establish the Strategic Training Needs - Establish and maintain the strategic training needs of the organization.	Training needs			
		Assessment analysis			
	SP 1.2-1: Determine Which Training Needs Are	Common project and support group training needs			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
agement and technical roles is established and maintained.	the Responsibility of the Organization - Determine which training needs are the responsibility of the organization and which will be left to the individual project or support group.	Training commitments			
	SP 1.3-1: Establish an Organizational Training Tactical Plan - Establish and maintain an organizational training tactical plan.	Organizational training tactical plan			
	SP 1.4-1: Establish Training Capability - Establish and maintain training capability to address organizational training needs.	Training materials and supporting artifacts			
SG 2: Provide Necessary Training - Training necessary for individuals to perform their roles effectively is provided.	SP 2.1-1: Deliver Training - Deliver the training following the organizational training tactical plan.	Delivered training course			
	SP 2.2-1: Establish Training Records - Establish and maintain records of the organizational training.	Training records			
		Training updates to the organizational repository			
	SP 2.3-1: Assess Training Effectiveness - Assess the effectiveness of the organization's training program.	Training-effectiveness surveys			
		Training program performance assessments			
		Instructor evaluation forms			
		Training examinations			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Organizational Process Performance					
SG 1: Establish Performance Baselines and Models - Baselines and models that characterize the expected process performance of the organization's set of standard processes are established and maintained.	SP 1.1-1: Select Processes - Select the processes or process elements in the organization's set of standard processes that are to be included in the organization's process performance analyses.	List of processes or process elements identified for process performance analyses			
	SP 1.2-1: Establish Process Performance Measures - Establish and maintain definitions of the measures that are to be included in the organization's process performance analyses.	Definitions for the selected measures of process performance			
	SP 1.3-1: Establish Quality and Process-Performance Objectives - Establish and maintain quantitative objectives for quality and process performance for the organization.	Organization's quality and process-performance objectives			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 1.4-1: Establish Process Performance Baselines - Establish and maintain the organization's process performance baselines.	Baseline data on the organization's process performance			
	SP 1.5-1: Establish Process Performance Models - Establish and maintain the process performance models for the organization's set of standard processes.	Process performance models			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Organizational Innovation and Deployment					
SG 1: Select Improvements – Process and technology improvements that contribute to meeting quality and process-performance objectives are selected.	SP 1.1-1: Collect and Analyze Improvement Proposals - Collect and analyze process- and technology-improvement proposals.	Analyzed process- and technology-improvement proposals			
	SP 1.2-1: Identify and Analyze Innovations - Identify and analyze innovative improvements that could increase the organization's quality and process performance.	Candidate innovative improvements			
		Analysis of proposed innovative improvements			
	SP 1.3-1: Pilot Improvements - Pilot process and technology improvements to select which ones to implement.	Pilot evaluation reports			
		Documented lessons learned from pilots			
	SP 1.4-1: Select Improvements for Deployment - Select process- and technology-improvement proposals for deployment across the organization.	Process- and technology-improvement proposals selected for deployment			
SG 2: Deploy Improvements - Measurable improvements to the organization's processes and technologies are continually and systematically deployed.	SP 2.1-1: Plan the Deployment - Establish and maintain the plans for deploying the selected process and technology improvements.	Deployment plan for selected process and technology improvements			
	SP 2.2-1: Manage the Deployment - Manage the deployment of the selected process and technology improvements.	Updated training materials (to reflect deployed process and technology improvements)			
		Documented results of process- and technology-improvement deployment activities			
		Revised process- and technology-improvement measures, objectives, priorities, and deployment plans			
	SP 2.3-1: Measure Improvement Effects - Measure the effects of the deployed process and technology improvements.	Documented measures of the effects resulting from the deployed process and technology improvements			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stake-holders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Project Planning					
SG 1: Establish Esti-	SP 1.1-1: Estimate the Scope of the Project -	Task descriptions	Y	Y	*PD02a*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
mates - Estimates of project planning parameters are established and maintained.	Establish a top-level work breakdown structure (WBS) to estimate the scope of the project.	Work package descriptions	Y	Y	*PD02a*
		WBS	Y	Y	*PD02b*
	SP 1.2-1: Establish Estimates of Work Product and Task Attributes - Establish and maintain estimates of the attributes of the work products and tasks.	Technical approach	Y	Y	*PD03a*
		Size and complexity of tasks and work products	Y		
		Estimating models	Y		
		Attribute estimates	Y		
	SP 1.3-1: Define Project Life Cycle - Define the project life-cycle phases upon which to scope the planning effort.	Project life-cycle phases	Y		
	SP 1.4-1: Determine Estimates of Effort and Cost - Estimate the project effort and cost for the work products and tasks based on estimation rationale.	Estimation rationale	Y		
		Project effort estimates	Y		
		Project cost estimates	Y		
SG 2: Develop a Project Plan - A project plan is established and maintained as the basis for managing the project.	SP 2.1-1: Establish the Budget and Schedule - Establish and maintain the project's budget and schedule.	Project schedules	Y		
		Schedule dependencies	Y		
		Project budget	Y		
	SP 2.2-1: Identify Project Risks - Identify and analyze project risks.	Identified risks	Y		
		Risk impacts and probability of occurrence	Y		
		Risk priorities	Y		
	SP 2.3-1: Plan for Data Management - Plan for the management of project data.	Data management plan			
		Master list of managed data			
		Data content and format description			
		Data requirements lists for acquirers and for suppliers			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
		Privacy requirements			
		Security requirements			
		Security procedures			
		Mechanism for data retrieval, reproduction, and distribution			
		Schedule for collection of project data			
		Listing of project data to be collected			
	SP 2.4-1: Plan for Project Resources - Plan for necessary resources to perform the project.	WBS work packages			
		WBS task dictionary			
		Staffing requirements based on project size and scope			
		Critical facilities/equipment list			
		Process/workflow definitions and diagrams			
		Program administration requirements list			
	SP 2.5-1: Plan for Needed Knowledge and Skills - Plan for knowledge and skills needed to perform the project.	Inventory of skill needs			
		Staffing and new hire plans			
		Databases (e.g., skills and training)			
	SP 2.6-1: Plan Stakeholder Involvement - Plan the involvement of identified stakeholders.	Stakeholder involvement plan			
	SP 2.7-1: Establish the Project Plan - Establish and maintain the overall project plan content.	Overall project plan			
		Integrated Master Plan	Y	Y	*PD04*
		Integrated Master Schedule	Y	Y	*PD05a*
		Systems Engineering Management Plan	Y	Y	*PD05c*
		Systems Engineering Master Schedule	Y	Y	*PD05b*
		Systems Engineering Detailed Schedule	Y	Y	*PD05a*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
SG 3: Obtain Commitment to the Plan - Commitments to the project plan are established and maintained.	SP 3.1-1: Review Plans that Affect the Project - Review all plans that affect the project to understand project commitments.	Record of the reviews of plans that affect the project			
	SP 3.2-1: Reconcile Work and Resource Levels - Reconcile the project plan to reflect available and estimated resources.	Revised methods and corresponding estimating parameters (e.g., better tools, use of off-the-shelf components)			
		Renegotiated budgets			
		Revised schedules			
		Revised requirements list			
		Renegotiated stakeholder agreements			
	SP 3.3-1: Obtain Plan Commitment - Obtain commitment from relevant stakeholders responsible for performing and supporting plan execution.	Documented requests for commitments			
		Documented commitments			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders	<Stakeholders include SE staff>	Y	Y	*PD02c, PD03b*
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Project Monitoring and Control					
SG 1: Monitor Project Against Plan - Actual performance and progress of the project are monitored against the project plan.	SP 1.1-1: Monitor Project Planning Parameters - Monitor the actual values of the project planning parameters against the project plan.	Records of project performance	Y	Y	*Perf01* *Perf02b* *Perf02e* *Cont09* *Cont13*
		Records of significant deviations	Y	Y	Perf02d
	SP 1.2-1: Monitor Commitments - Monitor commitments against those identified in the project plan.	Records of commitment reviews			
	SP 1.3-1: Monitor Project Risks - Monitor risks against those identified in the project plan.	Records of project risk monitoring	Y	Y	*PD11c*
	SP 1.4-1: Monitor Data Management - Monitor the management of project data against the project plan.	Records of data management			
	SP 1.5-1: Monitor Stakeholder Involvement - Monitor stakeholder involvement against the project plan.	Records of stakeholder involvement			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 1.6-1: Conduct Progress Reviews - Periodically review the project's progress, performance, and issues.	Documented project review results	Y	Y	*RD12*
	SP 1.7-1: Conduct Milestone Reviews - Review the accomplishments and results of the project at selected project milestones.	Documented milestone review results	Y	Y	*V&V03*
SG 2: Manage Corrective Action to Closure - Corrective actions are managed to closure when the project's performance or results deviate significantly from the plan.	SP 2.1-1: Analyze Issues - Collect and analyze the issues and determine the corrective actions necessary to address the issues.	List of issues needing corrective actions	Y	Y	*Operf05* *Operf06* *V&V02d*
	SP 2.2-1: Take Corrective Action - Take corrective action on identified issues.	Corrective action plan	Y		
	SP 2.3-1: Manage Corrective Action - Manage corrective actions to closure.	Corrective action results	Y	Y	V&V02d
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Supplier Agreement Management					
SG 1: Establish Supplier Agreements - Agreements with the suppliers are established and maintained.	SP 1.1-1: Determine Acquisition Type - Determine the type of acquisition for each product or product component to be acquired.	List of the acquisition types that will be used for all products and product components to be acquired			
	SP 1.2-1: Select Suppliers - Select suppliers based on an evaluation of their ability to meet the specified requirements and established criteria.	List of candidate suppliers			
		Preferred supplier list			
		Rationale for selection of suppliers			
		Advantages and disadvantages of candidate suppliers			
		Evaluation criteria			
		Solicitation materials and requirements			
	SP 1.3-1: Establish Supplier Agreements - Establish and maintain formal agreements with the supplier.	Statements of work			
		Contracts			
		Memoranda of agreement			
		Licensing agreement			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
SG 2: Satisfy Supplier Agreements - Agreements with the suppliers are satisfied by both the project and the supplier.	SP 2.1-1: Review COTS Products - Review candidate COTS products to ensure they satisfy the specified requirements that are covered under a supplier agreement.	Trade studies	Y		
		Price lists	Y		
		Evaluation criteria	Y		
		Supplier performance reports	Y		
		Reviews of COTS products	Y		
	SP 2.2-1: Execute the Supplier Agreement - Perform activities with the supplier as specified in the supplier agreement.	Supplier progress reports and performance measures			
		Supplier review materials and reports			
		Action items tracked to closure			
		Documentation of product and document deliveries			
	SP 2.3-1: Accept the Acquired Product - Ensure that the supplier agreement is satisfied before accepting the acquired product.	Acceptance test procedures			
		Acceptance test results			
		Discrepancy reports or corrective action plans			
	SP 2.4-1: Transition Products - Transition the acquired products from the supplier to the project.	Transition plans			
		Training reports			
		Support and maintenance reports			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Integrated Project Management for IPPD					
SG 1: Use the Project's Defined Process - The project is conducted using a defined process that is tailored from the organization's set of standard processes.	SP 1.1-1: Establish the Project's Defined Process - Establish and maintain the project's defined process.	The project's defined process			
	SP 1.2-1: Use Organizational Process Assets for Planning Project Activities - Use the organizational process assets and measurement repository for estimating and planning the project's activities.	Project estimates			
		Project plans			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 1.3-1: Integrate Plans - Integrate the project plan and the other plans that affect the project to describe the project's defined process.	Integrated plans			
	SP 1.4-1: Manage the Project Using the Integrated Plans - Manage the project using the project plan, the other plans that affect the project, and the project's defined process.	Work products created by performing the project's defined process			
		Collected measures ("actuals") and progress records or reports			
		Revised requirements, plans, and commitments			
		Integrated plans			
	SP 1.5-1: Contribute to the Organizational Process Assets - Contribute work products, measures, and documented experiences to the organizational process assets.	Proposed improvements to the organizational process assets			
		Actual process and product measures collected from the project			
		Documentation (e.g., exemplary process descriptions, plans, training modules, checklists, and lessons learned)			
SG 2: Coordinate and Collaborate with Relevant Stakeholders - Coordination and collaboration of the project with relevant stakeholders is conducted.	SP 2.1-1: Manage Stakeholder Involvement - Manage the involvement of the relevant stakeholders in the project.	Agendas and schedules for collaborative activities			
		Documented issues (e.g., issues with customer requirements, product and product-component requirements, product architecture, and product design)			
		Recommendations for resolving relevant stakeholder issues			
	SP 2.2-1: Manage Dependencies - Participate with relevant stakeholders to identify, negotiate, and track critical dependencies.	Defects, issues, and action items resulting from reviews with relevant stakeholders			
		Critical dependencies			
		Commitments to address critical dependencies			
		Status of critical dependencies			
	SP 2.3-1: Resolve Coordination Issues - Resolve issues with relevant stakeholders.	Relevant stakeholder coordination issues			
		Status of relevant stakeholder coordination issues			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
SG 3: Use the Project's Shared Vision for IPPD - The project is conducted using the project's shared vision.	SP 3.1-1: Define Project's Shared-Vision Context - Identify expectations, constraints, interfaces, and operational conditions applicable to the project's shared vision.	Organizational expectations and constraints that apply to the project			
		Summary of project members' personal aspirations for the project			
		External interfaces that the project is required to observe			
		Operational conditions that affect the project's activities			
		Project's shared-vision context			
	SP 3.2-1: Establish the Project's Shared Vision - Establish and maintain a shared vision for the project.	Meeting minutes for team-building exercises			
		Shared vision and objective statements			
		Statement of values and principles			
		Communications strategy			
		Handbook for new members of the project			
		Presentations to relevant stakeholders			
		Published principles, shared-vision statement, mission statement, and objectives (e.g., posters, wallet cards published on posters suitable for wall hanging)			
SG 4: Organize Integrated Teams for IPPD - The integrated teams needed to execute the project are identified, defined, structured, and tasked.	SP 4.1-1: Determine Integrated Team Structure for the Project - Determine the integrated team structure that will best meet the project objectives and constraints.	Assessments of the product and product architectures, including risk and complexity	Y		
		Integrated team structures based on the WBS and adaptations	Y	Y	*Proj05* *Proj06*
		Alternative concepts for integrated team structures that include responsibilities, scope, and interfaces	Y		
		Selected integrated team structure	Y		

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 4.2-1: Develop a Preliminary Distribution of Requirements to Integrated Teams - Develop a preliminary distribution of requirements, responsibilities, authorities, tasks, and interfaces to teams in the selected integrated team structure.	Preliminary distribution of integrated team authorities and responsibilities	Y		
		Preliminary distribution of the work product requirements, technical interfaces, and business (e.g., cost accounting, project management) interfaces each integrated team will be responsible for satisfying	Y		
	SP 4.3-1: Establish Integrated Teams - Establish and maintain teams in the integrated team structure.	A list of project integrated teams	Y		
		List of team leaders	Y		
		Responsibilities and authorities for each integrated team	Y	Y	*Proj03*
		Requirements allocated to each integrated team	Y		
		Measures for evaluating the performance of integrated teams	Y	Y	*Proj04*
		Quality assurance reports	Y		
		Periodic status reports	Y		
		New integrated team structures	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Risk Management					
SG 1: Prepare for Risk Management - Preparation for risk management is conducted.	SP 1.1-1: Determine Risk Sources and Categories - Determine risk sources and categories.	Risk source lists (external and internal)			
		Risk categories list			
	SP 1.2-1: Define Risk Parameters - Define the parameters used to analyze and categorize risks, and the parameters used to control the risk management effort.	Risk evaluation, categorization, and prioritization criteria			
		Risk management requirements (control and approval levels, reassessment intervals, etc.)			
	SP 1.3-1: Establish a Risk Management Strategy - Establish and maintain the strategy to be used for risk management.	Project risk management strategy			
SG 2: Identify and Analyze Risks - Risks are	SP 2.1-1: Identify Risks - Identify and document the risks.	List of identified risks, including the context, conditions, and consequences of risk occurrence	Y	Y	*PD11a*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
identified and analyzed to determine their relative importance.	SP 2.2-1: Evaluate, Categorize, and Prioritize Risks - Evaluate and categorize each identified risk using the defined risk categories and parameters, and determine its relative priority.	List of risks, with a priority assigned to each risk	Y	Y	
SG 3: Mitigate Risks - Risks are handled and mitigated, where appropriate, to reduce adverse impacts on achieving objectives.	SP 3.1-1: Develop Risk Mitigation Plans - Develop a risk mitigation plan for the most important risks to the project, as defined by the risk management strategy.	Documented handling options for each identified risk	Y	Y	
		Risk mitigation plans	Y	Y	*PD11b*
		Contingency plans	Y	Y	*PD11b*
		List of those responsible for tracking and addressing each risk	Y	Y	
	SP 3.2-1: Implement Risk Mitigation Plans - Monitor the status of each risk periodically and implement the risk mitigation plan as appropriate.	Updated lists of risk status			
		Updated assessments of risk likelihood, consequence, and thresholds			
		Updated lists of risk-handling options			
		Updated list of actions taken to handle risks			
		Risk mitigation plans			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Integrated Teaming					
SG 1: Establish Team Composition - A team composition that provides the knowledge and skills required to deliver the team's product is established and maintained.	SP 1.1-1: Identify Team Tasks - Identify and define the team's specific internal tasks to generate the team's expected output.	Descriptions of internal work tasks			
		List of results the team is expected to achieve for all work tasks			
	SP 1.2-1: Identify Needed Knowledge and Skills - Identify the knowledge, skills, and functional expertise needed to perform team tasks.	List of disciplines or functions required to perform the tasks			
		List of the knowledge, key skills, and critical expertise			
		Initial profiles of team skills and knowledge for the core team and the extended team			
	SP 1.3-1: Assign Appropriate Team Members - Assign the appropriate personnel to be team members based on required knowledge and skills.	Set of selection criteria			
		Revised skills matrix and knowledge profiles			
		List of team members			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
		List of the level of effort and resources, including access to staff, to perform each team function			
SG 2: Govern Team Operation - Operation of the integrated team is governed according to established principles.	SP 2.1-1: Establish a Shared Vision - Establish and maintain a shared vision for the integrated team that is aligned with any overarching or higher level vision.	Boundary conditions and interfaces within which the team must operate			
		Documented shared vision			
		Presentation materials of the shared-vision statement suitable for team members and various audiences that need to be informed			
	SP 2.2-1: Establish a Team Charter - Establish and maintain a team charter based on the integrated team's shared vision and overall team objectives.	Team charter			
		Procedures for setting the expectations for the work to be done and for measuring team performance			
		List of critical success factors			
		List of specific strategies the team expects to employ			
	SP 2.3-1: Define Roles and Responsibilities - Clearly define and maintain each team member's roles and responsibilities.	Descriptions of roles and responsibilities			
		Assignment statements			
		Responsibility matrix			
	SP 2.4-1: Establish Operating Procedures - Establish and maintain integrated team operating procedures.	Operating procedures and ground rules			
		Procedures for work expectations and performance measures			
	SP 2.5-1: Collaborate among Interfacing Teams - Establish and maintain collaboration among interfacing teams.	Work product and process deployment charts			
		Input to the integrated master plan and integrated schedules			
		Team work plans			
		Commitment lists			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stake-holders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Integrated Supplier Management					
SG 1: Analyze and Se-	SP 1.1-1: Analyze Potential Sources of Products -	List of potential sources of products that might be acquired			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
lect Sources of Products - Potential sources of products that best fit the needs of the project are identified, analyzed, and selected.	Identify and analyze potential sources of products that may be used to satisfy the project's requirements.	Market studies			
		Trade studies			
		Information about potential sources such as past performance, post-delivery support, corporate viability, and risks			
	SP 1.2-1: Evaluate and Determine Sources of Products - Use a formal evaluation process to determine which sources of custom-made and off-the-shelf products to use.	Analysis and evaluation reports			
		Revised list of product sources			
SG 2: Coordinate Work with Suppliers - Work is coordinated with suppliers to ensure the supplier agreement is executed appropriately.	SP 2.1-1: Monitor Selected Supplier Processes - Monitor and analyze selected processes used by the supplier.	List of processes selected for monitoring			
		Activity reports			
		Performance reports			
		Performance curves			
		Discrepancy reports			
	SP 2.2-1: Evaluate Selected Supplier Work Products - For custom-made products, evaluate selected supplier work products.	List of work products selected for monitoring			
		Activity reports			
		Discrepancy reports			
	SP 2.3-1: Revise the Supplier Agreement or Relationship - Revise the supplier agreement or relationship, as appropriate, to reflect changes in conditions.	Revisions to the supplier agreement			
		Revisions to the project's and supplier's processes and work products			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stake-holders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Quantitative Project Management					
SG 1: Quantitatively Manage the Project - The project is quantitatively managed using quality and process-performance objectives.	SP 1.1-1: Establish the Project's Objectives - Establish and maintain the project's quality and process-performance objectives.	The project's quality and process-performance objectives			
	SP 1.2-1: Compose the Defined Process - Select the subprocesses that compose the project's defined process based on historical stability and capability data.	Criteria used in identifying which subprocesses are valid candidates for inclusion in the project's defined process			
		Candidate subprocesses for inclusion in the project's defined process			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
		Subprocesses to be included in the project's defined process			
		Identified risks when selected subprocesses lack a process performance history			
	SP 1.3-1: Select the Subprocesses that Will Be Statistically Managed - Select the subprocesses of the project's defined process that will be statistically managed.	Quality and process-performance objectives that will be addressed by statistical management			
		Criteria used in selecting which subprocesses will be statistically managed			
		Subprocesses that will be statistically managed			
		Identified process and product attributes of the selected subprocesses that should be measured and controlled			
	SP 1.4-1: Manage Project Performance - Monitor the project to determine whether the project's objectives for quality and process performance will be satisfied, and identify corrective action as appropriate.	Estimates (predictions) of the achievement of the project's quality and process-performance objectives			
		Documentation of the risks in achieving the project's quality and process-performance objectives			
		Documentation of actions needed to address the deficiencies in achieving the project's objectives			
SG 2: Statistically Manage Subprocess Performance - The performance of selected subprocesses within the project's defined process is statistically managed.	SP 2.1-1: Select Measures and Analytic Techniques - Select the measures and analytic techniques to be used in statistically managing the selected subprocesses.	Definitions of the measures and analytic techniques to be used in (or proposed for) statistically managing the subprocesses			
		Operational definitions of the measures, their collection points in the subprocesses, and how the integrity of the measures will be determined			
		Traceability of measures back to the project's quality and process-performance objectives			
		Instrumented organizational support environment to support automatic data collection			
	SP 2.2-1: Apply Statistical Methods to Understand	Collected measures			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	Variation - Establish and maintain an understanding of the variation of the selected subprocesses using the selected measures and analytic techniques.	Natural bounds of process performance for each measured attribute of each selected subprocess			
		Process performance compared to the natural bounds of process performance for each measured attribute of each selected subprocess			
	SP 2.3-1: Monitor Performance of the Selected Subprocesses - Monitor the performance of the selected subprocesses to determine their capability to satisfy their quality and process-performance objectives, and identify corrective action as necessary.	Natural bounds of process performance for each selected subprocess compared to its established (derived) objectives			
		For each subprocess, its process capability			
		For each subprocess, the actions needed to address deficiencies in its process capability			
	SP 2.4-1: Record Statistical Management Data - Record statistical and quality management data in the organization’s measurement repository.	Statistical and quality management data recorded in the organization’s measurement repository			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
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	GP 2.7: Identify and Involve Relevant Stakeholders				
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	GP 2.9: Objectively Evaluate Adherence				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
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	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Requirements Management					
SG 1: Manage Requirements - Requirements are managed and inconsistencies with project plans and work products are identified.	SP 1.1-1: Obtain an Understanding of Requirements - Develop an understanding with the requirements providers on the meaning of the requirements.	Lists of criteria for distinguishing appropriate requirements providers	Y	Y	*RD04*
		Criteria for evaluation and acceptance of requirements	Y	Y	*RD05*
		Results of analyses against criteria	Y	Y	
		An agreed-to set of requirements	Y	Y	*RD06*
	SP 1.2-2: Obtain Commitment to Requirements - Obtain commitment to the requirements from the project participants.	Requirements impact assessments	Y	Y	*RD07*
		Documented commitments to requirements and requirements changes	Y	Y	
	SP 1.3-1: Manage Requirements Changes - Manage changes to the requirements as they evolve during the project.	Requirements status	Y	Y	
		Requirements database	Y		
		Requirements decision database	Y		
	SP 1.4-2: Maintain Bidirectional Traceability of Requirements - Maintain bidirectional traceability among the requirements and the project plans	Requirements traceability matrix	Y	Y	
		Requirements tracking system	Y	Y	*RD09*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	and work products.				
	SP 1.5-1: Identify Inconsistencies between Project Work and Requirements - Identify inconsistencies between the project plans and work products and the requirements.	Documentation of inconsistencies including sources, conditions, and rationale	Y		
		Corrective actions	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations		Y	Y	*RD10a*
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an	GP 5.1: Ensure Continuous Process Improvement				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Optimizing Process	GP 5.2: Correct Root Causes of Problem				
Requirements Development					
SG 1: Develop Customer Requirements - Stakeholder needs, expectations, constraints, and interfaces are collected and translated into customer requirements.	SP 1.1-1: Collect Stakeholder Needs - Identify and collect stakeholder needs, expectations, constraints, and interfaces for all phases of the product life cycle.				
	SP 1.1-2: Elicit Needs - Elicit stakeholder needs, expectations, constraints, and interfaces for all phases of the product life cycle.				
	SP 1.2-1: Develop the Customer Requirements - Transform stakeholder needs, expectations, constraints, and interfaces into customer requirements.	Customer requirements	Y	Y	*RD01a*
		Customer constraints on the conduct of verification	Y		
		Customer constraints on the conduct of validation	Y		
SG 2: Develop Product Requirements - Customer requirements are refined and elaborated to develop product and product-component requirements.	SP 2.1-1: Establish Product and Product-Component Requirements - Establish and maintain product and product-component requirements, which are based on the customer requirements.	Derived requirements	Y	Y	*RD01b*
		Product requirements	Y	Y	
		Product-component requirements	Y		
	SP 2.2-1: Allocate Product-Component Requirements - Allocate the requirements for each product component.	Requirement allocation sheets	Y	Y	*RD02*
		Provisional requirement allocations	Y		
		Design constraints	Y		
		Derived requirements	Y	Y	
		Relationships among derived requirements	Y		
	SP 2.3-1: Identify Interface Requirements - Identify interface requirements.	Interface requirements	Y	Y	
SG 3: Analyze and Vali-	SP 3.1-1: Establish Operational Concepts and	Operational concept	Y	Y	*RD03a*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
date Requirements - The requirements are analyzed and validated, and a definition of required functionality is developed.	Scenarios - Establish and maintain operational concepts and associated scenarios.	Product installation, operational, maintenance, and support concepts	Y	Y	*RD03c*
		Disposal concepts	Y		
		Use cases	Y	Y	*RD03b*
		Timeline scenarios	Y		
		New requirements	Y		
	SP 3.2-1: Establish a Definition of Required Functionality - Establish and maintain a definition of required functionality.	Functional architecture	Y		
		Activity diagrams and use cases	Y		
		Object-oriented analysis with services identified	Y		
	SP 3.3-1: Analyze Requirements - Analyze requirements to ensure that they are necessary and sufficient.	Requirements defects reports	Y		
		Proposed requirements changes to resolve defects	Y		
		Key requirements	Y		
		Technical performance measures	Y		
	SP 3.4-3: Analyze Requirements to Achieve Balance - Analyze requirements to balance stakeholder needs and constraints.	Assessment of risks related to requirements	Y		
	SP 3.5-1: Validate Requirements - Validate requirements to ensure the resulting product will perform appropriately in its intended-use environment.	Results of requirements validation	Y		
	SP 3.5-2: Validate Requirements with Comprehensive Methods - Validate requirements to ensure the resulting product will perform as intended in the user's environment using multiple techniques as appropriate.	Record of analysis methods and results	Y		

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Technical Solution					
SG 1: Select Product-	SP 1.1-1: Develop Alternative Solutions and Se-	Alternative solutions	Y	Y	*RD12*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Component Solutions - Product or product-component solutions are selected from alternative solutions.	lection Criteria - Develop alternative solutions and selection criteria.	Selection criteria	Y	Y	*RD12*
	SP 1.1-2: Develop Detailed Alternative Solutions and Selection Criteria - Develop detailed alternative solutions and selection criteria.	Alternative solution screening criteria	Y	Y	
		Evaluations of new technologies	Y		
		Alternative solutions	Y	Y	
		Selection criteria for final selection	Y	Y	
	SP 1.2-2: Evolve Operational Concepts and Scenarios - Evolve the operational concept, scenarios, and environments to describe the conditions, operating modes, and operating states specific to each product component.	Product-component operational concepts, scenarios, and environments for all product-related life-cycle processes (e.g., operations, support, training, manufacturing, deployment, fielding, delivery, and disposal)	Y		
		Timeline analyses of product-component interactions	Y		
		Use cases	Y		
	SP 1.3-1: Select Product-Component Solutions - Select the product-component solutions that best satisfy the criteria established.	Product-component selection decisions and rationale	Y	Y	
		Documented relationships between requirements and product components	Y		
		Documented solutions, evaluations, and rationale	Y		
SG 2: Develop the Design - Product or product-component designs are developed.	SP 2.1-1: Design the Product or Product Component - Develop a design for the product or product component.	Product architecture	Y	Y	*IF03a, IF03b*
		Product-component designs	Y		
	SP 2.2-3: Establish a Technical Data Package	Technical data package	Y		
	SP 2.3-1: Establish Interface Descriptions - Establish and maintain the solution for product-component interfaces.	Interface design	Y	Y	*IF01*
		Interface design documents	Y	Y	*IF02*
	SP 2.3-3: Design Interfaces Using Criteria - Design comprehensive product-component interfaces in terms of established and maintained	Interface design specifications	Y		
		Interface control documents	Y	Y	*IF02*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	criteria.	Interface specification criteria	Y		
		Rationale for selected interface design	Y		
	SP 2.4-3: Perform Make, Buy, or Reuse Analyses - Evaluate whether the product components should be developed, purchased, or reused based on established criteria.	Criteria for design and product-component reuse	Y		
		Make-or-buy analyses	Y	Y	
		Guidelines for choosing COTS product components	Y	Y	*IF04*
SG 3: Implement the Product Design - Product components, and associated support documentation, are implemented from their designs.	SP 3.1-1: Implement the Design - Implement the designs of the product components.	Implemented design	Y		
		Standard Parts Lists	Y		
		Standard drawing requirements	Y		
		International Organization for Standardization (ISO) T3303 standards for manufactured parts	Y		
	SP 3.2-1: Develop Product Support Documentation - Develop and maintain the end-use documentation.	End-user training materials	Y		
		User's manual	Y		
		Operator's manual	Y		
		Maintenance manual	Y		
		Online help	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.7: Identify and Involve Relevant Stake-holders		Y	Y	*RD11*
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Product Integration					
SG 1: Prepare for Prod-uct Integration - Prepara-tion for product integra-tion is conducted.	SP 1.1-1: Determine Integration Sequence - De-termine the product-component integration se-quence.	Product integration sequence	Y		
		Rationale for selecting or rejecting integration sequences	Y		
	SP 1.2-2: Establish the Product Integration Envi-ronment - Establish and maintain the environment needed to support the integration of the product components.	Verified environment for product integration	Y		
		Support documentation for the product integration environment	Y		
	SP 1.3-3: Establish Product Integration Proce-dures and Criteria - Establish and maintain pro-cedures and criteria for integration of the product components.	Product integration procedures	Y	Y	*IF05*
		Product integration criteria	Y		
SG 2: Ensure Interface	SP 2.1-1: Review Interface Descriptions for Com-	Categories of interfaces	Y		

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Compatibility - The product-component interfaces, both internal and are compatible.	pleteness - Review interface descriptions for coverage and completeness.	List of interfaces per category	Y		
		Mapping of the interfaces to the product components and product integration environment	Y		
	SP 2.2-1: Manage Interfaces - Manage internal and external interface definitions, designs, and changes for products and product components.	Table of relationships among the product components and the external environment (e.g., main power supply, fastening product, computer bus system)	Y		
		Table of relationships between the different product components	Y		
		List of agreed-to interfaces defined for each pair of product components, when applicable	Y		
		Reports from the interface control working group meetings	Y		
		Action items for updating interfaces	Y		
		Application program interface (API)	Y		
		Updated interface description or agreement	Y		
SG 3: Assemble Product Components and Deliver the Product - Verified product components are assembled and the integrated, verified, and validated product is delivered.	SP 3.1-1: Confirm Readiness of Product Components for Integration - Confirm, prior to assembly, that each product component required to assemble the product has been properly identified, functions according to its description, and that the product-component interfaces comply with the interface descriptions.	Acceptance documents for the received product components			
		Delivery receipts			
		Checked packing lists			
		Exception reports			
		Waivers			
	SP 3.2-1: Assemble Product Components - Assemble product components according to the product integration sequence and available procedures.	Assembled product or product components			
	SP 3.3-1: Evaluate Assembled Product Compo-	Exception reports			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	nents - Evaluate assembled product components for interface compatibility.	Interface evaluation reports			
		Product integration summary reports			
	SP 3.4-1: Package and Deliver the Product or Product Component - Package the assembled product or product component and deliver it to the appropriate customer.	Packaged product or product components			
		Delivery documentation			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Verification					
SG 1: Prepare for Verification - Preparation for verification is conducted.	SP 1.1-1: Select Work Products for Verification - Select the work products to be verified and the verification methods that will be used for each.	Lists of work products selected for verification	Y		
		Verification methods for each selected work product	Y		
	SP 1.2-2: Establish the Verification Environment - Establish and maintain the environment needed to support verification.	Verification environment	Y		
	SP 1.3-3: Establish Verification Procedures and Criteria - Establish and maintain verification procedures and criteria for the selected work products.	Verification procedures	Y	Y	*V&V01a*
		Verification criteria	Y	Y	*V&V01b*
SG 2: Perform Peer Reviews - Peer reviews are performed on selected work products.	SP 2.1-1: Prepare for Peer Reviews - Prepare for peer reviews of selected work products.	Peer review schedule	Y		
		Peer review checklist	Y		
		Entry and exit criteria for work products	Y	Y	*V&V02a*
		Criteria for requiring another peer review	Y		
		Peer review training material	Y	Y	*V&V02b*
		Selected work products to be reviewed	Y	Y	*V&V02c*
	SP 2.2-1: Conduct Peer Reviews - Conduct peer reviews on selected work products and identify issues resulting from the peer review.	Peer review results	Y	Y	
		Peer review issues	Y	Y	*V&V02e*
		Peer review data	Y		
	SP 2.3-2: Analyze Peer Review Data - Analyze	Peer review data	Y		

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	data about preparation, conduct, and results of the peer reviews.	Peer review action items	Y	Y	*V&V02d*
	SG 3: Verify Selected Work Products – Selected work products are verified against their specified requirements.				
	SP 3.1-1: Perform Verification – Perform verification on the selected work products.	Verification results			
		Verification reports			
		Demonstrations			
		As-run procedures log			
	SP 3.2-2: Analyze Verification Results and Identify Corrective Action - Analyze the results of all verification activities and identify corrective action.	Analysis report (such as statistics on performances, causal analysis of nonconformances, comparison of the behavior between the real product and models, and trends)	Y		
		Trouble reports	Y	Y	
		Change requests for the verification methods, criteria, and environment	Y	Y	
		Corrective actions to verification methods, criteria, and/or environment	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.7: Identify and Involve Relevant Stake-holders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Validation					
SG 1: Prepare for Valida-tion - Preparation for validation is conducted.	SP 1.1-1: Select Products for Validation – Select products and product components to be validated and the validation methods that will be used for each.	Lists of products and product components selected for validation	Y		
		Validation methods for each product or product component	Y		
		Requirements for performing validation for each product or product com-ponent	Y		
		Validation constraints for each product or product component	Y		
	SP 1.2-2: Establish the Validation Environment - Establish and maintain the environment needed to support validation.	Validation environment	Y		
	SP 1.3-3: Establish Validation Procedures and	Validation procedures	Y	Y	*V&V04a*

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	Criteria - Establish and maintain procedures and criteria for validation.	Validation criteria	Y	Y	*V&V04b*
		Test and evaluation procedures for maintenance, training, and support	Y		
SG 2: Validate Product or Product Components - The product or product components are validated to ensure that they are suitable for use in their intended operating environment.	SP 2.1-1: Perform Validation - Perform validation on the selected products and product components.	Validation reports			
		Validation results			
		Validation cross-reference matrix			
		As-run procedures log			
		Operational demonstrations			
	SP 2.2-1: Analyze Validation Results - Analyze the results of the validation activities and identify issues.	Validation deficiency reports	Y		
		Validation issues	Y		
		Procedure change request	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
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	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Configuration Management					
SG 1: Establish Baselines - Baselines of identified work products are established.	SP 1.1-1: Identify Configuration Items - Identify the configuration items, components, and related work products that will be placed under configuration management.	Identified configuration items	Y	Y	*V&V05*
	SP 1.2-1: Establish a Configuration Management System - Establish and maintain a configuration management and change management system for controlling work products.	Configuration management system with controlled work products	Y		
		Configuration management system access control procedures	Y	Y	
		Change request database	Y	Y	
	SP 1.3-1: Create or Release Baselines - Create or release baselines for internal use and for delivery to the customer.	Baselines	Y	Y	*V&V08* *Perf01*
		Description of baselines	Y		
SG 2: Track and Control Changes - Changes to	SP 2.1-1: Track Change Requests – Track change requests for the configuration items.	Change requests	Y		

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
the work products under configuration management are tracked and controlled.	SP 2.2-1: Control Configuration Items - Control changes to the configuration items.	Revision history of configuration items	Y	Y	*V&V06*
		Archives of the baselines	Y	Y	*V&V08*
SG 3: Establish Integrity - Integrity of baselines is established and maintained.	SP 3.1-1: Establish Configuration Management Records – Establish and maintain records describing configuration items.	Revision history of configuration items	Y	Y	*V&V07*
		Change log	Y		
		Copy of the change requests	Y		
		Status of configuration items	Y		
		Differences between baselines	Y		
	SP 3.2-1: Perform Configuration Audits – Perform configuration audits to maintain integrity of the configuration baselines.	Configuration audit results	Y		
		Action items	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
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	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Process and Product Quality Assurance					
SG 1: Objectively Evaluate Processes and Work Products - Adherence of the performed process and associated work products and services to applicable process descriptions, standards, and procedures is objectively evaluated.	SP 1.1-1: Objectively Evaluate Processes - Objectively evaluate the designated performed processes against the applicable process descriptions, standards, and procedures.	Evaluation reports			
		Noncompliance reports			
		Corrective actions			
	SP 1.2-1: Objectively Evaluate Work Products and Services - Objectively evaluate the designated work products and services against the applicable process descriptions, standards, and procedures.	Evaluation reports			
		Noncompliance reports			
		Corrective actions			
SG 2: Provide Objective Insight - Noncompliance issues are objectively tracked and communicated, and resolution is ensured.	SP 2.1-1: Communicate and Ensure Resolution of Noncompliance Issues - Communicate quality issues and ensure resolution of noncompliance issues with the staff and managers.	Corrective action reports			
		Evaluation reports			
		Quality trends			
	SP 2.2-1: Establish Records - Establish and maintain records of the quality assurance activities.	Evaluation logs			
		Quality assurance reports			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
		Status reports of corrective actions			
		Reports of quality trends			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
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	GP 5.2: Correct Root Causes of Problem				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Measurement and Analysis					
SG 1: Align Measurement and Analysis Activities - Measurement objectives and activities are aligned with identified information needs and objectives.	SP 1.1-1: Establish Measurement Objectives - Establish and maintain measurement objectives that are derived from identified information needs and objectives.	Measurement objectives			
	SP 1.2-1: Specify Measures - Specify measures to address the measurement objectives.	Specifications of base and derived measures			
	SP 1.3-1: Specify Data Collection and Storage Procedures - Specify how measurement data will be obtained and stored.	Data collection and storage procedures			
		Data collection tools			
	SP 1.4-1: Specify Analysis Procedures - Specify how measurement data will be analyzed and reported.	Analysis specification and procedures			
		Data analysis tools			
SG 2: Provide Measurement Results - Measurement results that address identified information needs and objectives are provided.	SP 2.1-1: Collect Measurement Data - Obtain specified measurement data.	Base and derived measurement data sets			
		Results of data integrity tests			
	SP 2.2-1: Analyze Measurement Data - Analyze and interpret measurement data.	Analysis results and draft reports			
	SP 2.3-1: Store Data and Results – Manage and store measurement data, measurement specifications, and analysis results.	Stored data inventory			
	SP 2.4-1: Communicate Results - Report results of measurement and analysis activities to all relevant stakeholders.	Delivered reports and related analysis results			
		Contextual information or guidance to aid in the interpretation of analysis results			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stake-holders				
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	GP 2.10: Review Status with Higher Level Man-agement				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
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GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Decision Analysis and Resolution					
SG 1: Evaluate Alterna-tives - Decisions are based on an evaluation of alternatives using established criteria.	SP 1.1-1: Establish Guidelines for Decision Anal-ysis - Establish and maintain guidelines to deter-mine which issues are subject to a formal evalua-tion process.	Guidelines for when to apply a formal evaluation process	Y		
	SP 1.2-1: Establish Evaluation Criteria - Establish and maintain the criteria for evaluating alterna-tives, and the relative ranking of these criteria.	Documented evaluation criteria	Y		
		Rankings of criteria importance	Y		

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 1.3-1: Identify Alternative Solutions - Identify alternative solutions to address issues.	Identified alternatives	Y		
	SP 1.4-1: Select Evaluation Methods - Select the evaluation methods.	Selected evaluation methods	Y		
	SP 1.5-1: Evaluate Alternatives - Evaluate alternative solutions using the established criteria and methods.	Evaluation results	Y		
	SP 1.6-1: Select Solutions - Select solutions from the alternatives based on the evaluation criteria.	Recommended solutions to address significant issues	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
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	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				
Organizational Environment for Integration					
SG 1: Provide IPPD Infrastructure - An infrastructure that maximizes the productivity of people and affects the collaboration necessary for integration is provided.	SP 1.1-1: Establish the Organization's Shared Vision - Establish and maintain a shared vision for the organization.	Organization's shared vision			
		Evaluations of the organization's shared vision			
		Guidelines for shared-vision building within projects and integrated teams			
	SP 1.2-1: Establish an Integrated Work Environment - Establish and maintain an integrated work environment that supports IPPD by enabling collaboration and concurrent development.	Requirements for the integrated work environment			
		Design of the integrated work environment			
		Integrated work environment			
	SP 1.3-1: Identify IPPD-Unique Skill Requirements - Identify the unique skills needed to support the IPPD environment.	IPPD strategic training needs			
		IPPD tactical training needs			
SG 2: Manage People for Integration - People are managed to nurture the integrative and collaborative behaviors of an IPPD environment.	SP 2.1-1: Establish Leadership Mechanisms - Establish and maintain leadership mechanisms to enable timely collaboration.	Guidelines for determining the degree of empowerment of people and integrated teams			
		Guidelines for setting leadership and decision-making context			
		Organizational process documentation for issue resolution			
	SP 2.2-1: Establish Incentives for Integration - Establish and maintain incentives for adopting and demonstrating integrative and collaborative behaviors at all levels of the organization.	Policies and procedures for performance appraisal and recognition that reinforce collaboration			
		Integrated team and individual recognition and rewards			

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	SP 2.3-1: Establish Mechanisms to Balance Team and Home Organization Responsibilities - Establish and maintain organizational guidelines to balance team and home organization responsibilities.	Organizational guidelines for balancing team and home organization responsibilities			
		Performance review process that considers both functional supervisor and team leader input			
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an	GP 5.1: Ensure Continuous Process Improvement				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
Optimizing Process	GP 5.2: Correct Root Causes of Problem				
Causal Analysis and Resolution					
SG 1: Determine Causes of Defects - Root causes of defects and other problems are systematically determined.	SP 1.1-1: Select Defect Data for Analysis - Select the defects and other problems for analysis.	Defect and problem data selected for further analysis	Y		
	SP 1.2-1: Analyze Causes - Perform causal analysis of selected defects and other problems and propose actions to address them.	Action proposal	Y		
SG 2: Address Causes of Defects - Root causes of defects and other problems are systematically addressed to prevent their future occurrence.	SP 2.1-1: Implement the Action Proposals - Implement the selected action proposals that were developed in causal analysis.	Action proposals selected for implementation	Y		
		Improvement proposals	Y		
	SP 2.2-1: Evaluate the Effect of Changes - Evaluate the effect of changes on process performance.	Measures of performance and performance change	Y		
	SP 2.3-1: Record Data - Record causal analysis and resolution data for use across the project and organization.	Causal analysis and resolution records	Y		
GG 1: Achieve Specific Goals	GP 1.1: Perform Base Practices				
GG 2: Institutionalize a Managed Process	GP 2.1: Establish an Organizational Policy				
	GP 2.2: Plan the Process				
	GP 2.3: Provide Resources				
	GP 2.4: Assign Responsibility				
	GP 2.5: Train People				
	GP 2.6: Manage Configurations				
	GP 2.7: Identify and Involve Relevant Stakeholders				

Goal	PRACTICE	WORK PRODUCT (WP)	SE WP	Key SE WP	Survey Question
	GP 2.8: Monitor and Control the Process				
	GP 2.9: Objectively Evaluate Adherence				
	GP 2.10: Review Status with Higher Level Management				
GG 3: Institutionalize a Defined Process	GP 3.1: Establish a Defined Process				
	GP 3.2: Collect Improvement Information				
GG 4: Institutionalize a Quantitatively Managed Process	GP 4.1: Establish Quantitative Objectives for the Process				
	GP 4.2: Stabilize Subprocess Performance				
GG 5: Institutionalize an Optimizing Process	GP 5.1: Ensure Continuous Process Improvement				
	GP 5.2: Correct Root Causes of Problem				

APPENDIX B Survey Questionnaire (annotated reproduction)

The Effectiveness of Systems Engineering: A Survey

Welcome to your personalized questionnaire for our survey on “The Effectiveness of Systems Engineering.” Our hope is that your participation will help your project and organization judge the effectiveness of their systems engineering practices relative to the successes and challenges reported by others throughout the industry.

Most of the information necessary to complete the questionnaire should be easily accessible or familiar to you or perhaps an informed designee. It should take about 30 to 45 minutes to complete the questionnaire. Please provide your best estimates if quantitative measurements are unavailable.

Please complete the questionnaire as candidly and completely as you possibly can. The results will be useful to you, us and others only to the extent that all survey participants do so. As always, information collected under promise of non disclosure by the SEI will be held in strict confidence. No attribution to individual organizations will be made. Results will be reported in summary aggregate form, similar to the SEI process maturity profiles. There is no need to hide weaknesses or embellish strengths.

Be sure to save your personalized URL if you have not already done so. It is -- *https://seir.sei.cmu.edu/feedback/SystemsEngineering.asp?ID=xxxxxxxx.* You or your designee may return to that URL and continue completing the questionnaire at any time. You also may save your work at any time. There are separate **Save** buttons for each section of the questionnaire. Please be sure that you are fully finished before you press the **Submit** button at the end of the questionnaire.

A detailed summary report of the survey results will be prepared by NDIA with the assistance of the Software Engineering Institute. For at least a full year, the report will be made available only to those who fully complete a survey questionnaire. The report will provide a baseline against which you can compare the performance of your project and organization. Scroll down to Authentication below for more information.

Thank you once again for your help with this important activity. And, please feel free to contact us at benchmark@sei.cmu.edu if you have any difficulty with the questionnaire.

Authentication

The summary survey report will be available via an authenticated Web site. To check on the status of the report from time to time, please save the following address:

https://seir.sei.cmu.edu/feedback/SystemsEngineeringSurveyResults.htm When the report is completed you will need your account name and the password you enter below to access it.

1. Your account name is: **<xxxxxxx>** *(randomly generated to protect your anonymity)*

2. Password (*Please choose a unique password of your own choosing* -- *protect your continued anonymity by avoiding anything that specifies or hints at the identity of yourself, your project, or your organization*)

You must enter a password to save your work. You will need the password to complete your questionnaire in more than one session. You will also need the password and account name in order to access the detailed survey report.

<*User defined Password*>

Analysis Data Code	
	About This Project
	The information gathered here and in the next few sections will be used by the survey analysts to categorize the participating projects and organizations in order to better understand the responses to subsequent questions about systems engineering practices and project performance
Proj01a – Proj01j	1. What phases of the integrated product life cycle are or will be included in this project? (*Please select as many as apply*) ❑ Concept Refinement ❑ Technology Development and Demonstration ❑ Development ❑ Manufacturing / Production ❑ Verification / Validation ❑ Training ❑ Deployment ❑ Operation ❑ Support ❑ Disposal

Analysis Data Code	
Proj02a – Proj02j	2. What phase or phases of the integrated product life cycle is this project presently executing? (*Please select as many as apply*) ❑ Concept Refinement ❑ Technology Development and Demonstration ❑ Development ❑ Manufacturing / Production ❑ Verification / Validation ❑ Training ❑ Deployment ❑ Operation ❑ Support ❑ Disposal
	Following are several statements that have been used to characterize various development projects. How well do the statements describe this project?
Proj03	3. This project uses integrated product teams (IPTs) ❑ Yes ❑ No (*Please continue with question 8 below*)
Proj04	4. This project makes effective use of integrated product teams (IPTs) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Proj05	5. Both the supplier and the acquirer actively participate in IPTs ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Proj06	6. My suppliers actively participate in IPTs ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Proj07a	7. This project has an IPT with assigned responsibility for systems engineering ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Proj07b	This project has Systems Engineering representation on each IPT ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	8. The project is technically challenging because... (*Please select one for each*)
Proj8a	...there is no precedent for what is being done ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code

Proj8b ...significant constraints are placed on the quality attributes (e.g. reliability, scalability, security, supportability, etc.) of the product

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj8c ...the size of the development effort is large

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj8d ...the technology needed for this project is not mature

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj8e ...there are extensive needs for interoperability with other systems

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj8f ...insufficient resources (e.g. people, funding) are available to support the project

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj8g ...insufficient skills and subject matter expertise are available to support the project

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj8h ...for other reasons (Please describe briefly)

Proj09 9. This project team has successfully completed projects similar to this in the past.

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

10. The requirements for this project ... (*Please select one for each*)

Proj10a ...are well-defined

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Proj10b ...have not changed significantly throughout the life of the project to-date

❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

About the Product

Analysis Data Code	
Prod01	1. Which selection best characterizes your customer? (*Please select one*) ❑ US Government (including DoD and other agencies) ❑ Prime Contractor ❑ Subcontractor
Prod02a	2. Who is acquiring this product? (*Please select one*) ❑ Army ❑ Navy/Marine ❑ Air Force ❑ NASA ❑ Homeland Defense ❑ DARPA ❑ Other Government Agency ❑ Commercial ❑ Other (*Please describe briefly*)
Prod3a – Prod3j	3. Who is the primary end user (or users) of this product? (*Please select as many as apply*) ❑ Army ❑ Navy/Marine ❑ Air Force ❑ NASA ❑ Homeland Defense ❑ DARPA ❑ Other Government Agency ❑ Commercial ❑ Other (*Please describe briefly*)

Analysis Data Code	
Prod4a	4. In the context of the ultimate product delivered to the end user, where does this project fit in the following hierarchy? (*Please select one*) ❑ System of Systems / Family of Systems ❑ System ❑ Subsystem ❑ Component (hardware and/or software) ❑ Process ❑ Material ❑ Other (*Please describe briefly*)
Prod5a – Prod5f	5. Where will this system resulting from this project be used? (*Please select as many as apply*) ❑ Land ❑ Air ❑ Sea ❑ Undersea ❑ Space ❑ Other (*Please describe briefly*)
	About the Contract
Cont01	1. What is the current total contract value of this project? (*Please specify in US dollars -- numbers only, without a dollar sign or commas*) US dollars ($)
Cont02	2. What is the current total planned duration of this project? (*Please specify*) Calendar months
Cont03	3. What was the initial contract value of this project? (*Please specify in US dollars -- numbers only, without a dollar sign or commas*) US dollars ($)

Analysis Data Code	
Cont04	4. What was the initial total planned duration of this project? (*Please specify*) [ ] Calendar months
Cont05	5. How many contract change orders have been received? (*Please specify a number, approximate if necessary*) [ ] Change orders
Cont06	6. Approximately how many person-years of effort are allocated to be spent on this project within your organization? (*Please specify a number*) [ ] Person years
Cont07	7. What program acquisition category (ACAT level) is your program classified at? (*Please select one*) ❑ Don't Know ❑ ACAT IAC ❑ ACAT IAM ❑ ACAT IC ❑ ACAT ID ❑ ACAT II ❑ ACAT III ❑ Other (*Please describe briefly*) [ ]
Cont08	8. What percentage of the total contract value is subcontracted to your suppliers? *(Please specify an approximate percentage -- without the percentage sign)* [ ] %
Cont09	9. What is the current completion status of this project? *(Please specify an approximate percentage -- without the percentage sign -- e.g., 60% complete)* [ ] % Complete

Analysis Data Code	
Cont10a – Cont10h	10. How many stakeholders (including internal and external) are involved in this project? *(Please select one for each)* [ ] Acquirers [ ] System integration contractors [ ] Maintenance contractors [ ] Development co-contractors (e.g., sister development programs) [ ] Development sub-contractors [ ] Oversight contractors [ ] Users [ ] Other *(Please describe briefly)* [ ]
Cont11	11. What percentage of the customer technical requirements were marked "To Be Determined" at time of contract award? (*Please specify* -- *numbers only, without the percentage sign*) [ ] %
Cont12	12. What percentage of the customer's technical requirements are currently marked "To Be Determined"? (*Please specify an approximate percentage* -- *without the percentage sign*) [ ] %
Cont13	13. Do you separately cost and track systems engineering activities? (*Please select one*) ❑ Yes ❑ No (Please continue with question 15) ❑ Don't know (Please continue with question 15)
Cont14a	14. Approximately what percentage of non-recurring engineering (NRE) does systems engineering represent? (*Please specify an approximate percentage* -- *without the percentage sign*) [ ] %

Analysis Data Code	
Cont14b	Is the NRE percentage estimated, or is it a measured value? (*Please select one*) ❑ Estimated ❑ Measured
Cont15a – Cont15n	15. What type of contract(s) was awarded for this project? (*Please select as many as apply*) ❑ Firm fixed price -- FAR 16.202 ❑ Fixed price with economic price adjustment -- FAR 16.203 ❑ Fixed price with prospective price redetermination -- FAR 16.205 ❑ Fixed ceiling with retroactive price redetermination -- FAR 16.206 ❑ Firm fixed price, level of effort -- FAR 16.207 ❑ Cost reimbursement -- FAR 16.302 ❑ Cost sharing -- FAR 16.303 ❑ Cost plus incentive fee -- FAR 16.304 ❑ Cost plus fixed fee -- FAR 16.306 ❑ Fixed price incentive -- FAR 16.403 ❑ Fixed price with award fees -- FAR 16.404 ❑ Cost plus award fee -- FAR 16.405 ❑ Other (*Please describe briefly*)

About the Organization

By "organization" we mean an administrative structure within which (possibly many) projects or similar work efforts are organized under common management and policies.

When thinking about your organization, please answer for the unit to which **this project** reports administratively, e.g., a site, division or department, not for a larger enterprise of which the organization to which you report may be a part.

1. Following are two statements that have been used to characterize various development organizations. How well do the statements describe this project's parent organization? (*Please select one for each*)

Analysis Data Code	
Org01a	This organization has successfully completed projects similar to this one in the past ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Org01b	Process improvement efforts in this organization have been directly related to systems engineering ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Org02	2. To what extent do the tailored processes followed by this project comply with the organization's standard processes? (*Please select one*) ❑ Highly compliant; processes closely followed ❑ Largely compliant; processes usually followed ❑ Moderately compliant; processes not always followed ❑ Not compliant; or processes not followed
Org03a – Org03k	3. What process improvement activities have been undertaken on this project? (*Please select as many as apply*) ❑ ISO 9000 ❑ Lean ❑ Six Sigma ❑ SE-CMM ❑ SW-CMM ❑ SECAM ❑ EIA-731 ❑ CMMI ❑ None ❑ Other (*Please describe briefly*)

Analysis Data Code

Org04

4. At what, if any, CMM or CMMI Maturity Level has this project's parent organization most recently been appraised? (*Please select one*)
   - ❑ Not appraised (*Please continue with question 7*)
   - ❑ Level 1 (Initial)
   - ❑ Level 2 (Managed)
   - ❑ Level 3 (Defined)
   - ❑ Level 4 (Quantitatively Managed)
   - ❑ Level 5 (Optimizing)

Org05

5. When was the organization's most recent appraisal? (*Please select one*)
   - ❑ Within the past 6 months
   - ❑ Within the past year
   - ❑ Within the past 2 years
   - ❑ More than 2 years ago

Org06

6. What model was used? (*Please select one*)
   - ❑ CMMI-SE/SW/IPPD/SS
   - ❑ CMMI-SE/SW/IPPD
   - ❑ CMMI-SE/SW
   - ❑ CMMI-SW

Org07

7. Has this project been objectively verified to be implementing processes consistent with a given CMM/CMMI maturity level? (*Please select one*)
   - ❑ Not verified
   - ❑ Level 1 (Initial)
   - ❑ Level 2 (Managed)
   - ❑ Level 3 (Defined)
   - ❑ Level 4 (Quantitatively Managed)
   - ❑ Level 5 (Optimizing)

Org08

8. Is anything else particularly important in characterizing your project, the organization within which it resides or the system that you are developing? (*Please describe here*)

Process Definition, Project Planning & Risk Management

Analysis Data Code

This and the next few sections ask you about the systems engineering activities performed on this project. Most of the questions ask about the existence and quality of tangible work products. Note that the pertinent information often may be distributed throughout multiple documents or other work products; it need not necessarily be located in one particular place.

Following are several statements about work products and activities that are sometimes used for systems development. Please use the following definitions to describe their use on **this** project:

Strongly Disagree The work product does not exist or is never used on this project.

Disagree The work product is of insufficient quality **or** is not used regularly at appropriate occasions on this project.

Agree The work product or practice is of good quality **and** it is used regularly on this project, although not necessarily as often as it could be.

Strongly Agree The work product or practice is of exceptional quality **and** it is used at nearly all appropriate occasions on this project.

Not Applicable This work product or practice does not apply to this project at the current stage of the project's life cycle (e.g., test reports do not exist because we are not yet in the verification phase of the project).

PD01

1. This project utilizes a documented set of systems engineering processes for the planning and execution of the project
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

2. This project has an accurate and up-to-date Work Breakdown Structure (WBS) that... (*Please select one for each*)

PD02a

... includes task descriptions and work package descriptions
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

PD02b

... is based upon the product structure
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code	
PD02c	... is developed with the active participation of those who perform the systems engineering activities ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD02d	... is developed with the active participation of all relevant stakeholders, e.g., developers, maintainers, testers, inspectors, etc. ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	3. This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development)... (*Please select one for each*)
PD03a	...is complete, accurate and up-to-date ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD03b	...is developed with the active participation of those who perform the systems engineering activities ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD03c	...is developed with the active participation of all appropriate functional stakeholder ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	4. This project has a top-level plan, such as an Integrated Master Plan (IMP), that... (Please select one for each)
PD04a	...is an event-driven plan (i.e., each accomplishment is tied to a key project event) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD04b	...documents significant accomplishments with pass/fail criteria for both business and technical elements of the project ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD04c	...is consistent with the WBS ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	5. This project has an integrated event-based schedule that... (*Please select one for each*)

Analysis Data Code	
PD05a	...is structured as a networked, multi-layered schedule of project tasks required to complete the work effort ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD05b	...contains a compilation of key technical accomplishments (e.g., a Systems Engineering Master Schedule) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD05c	...references measurable criteria (usually contained in the Integrated Master Plan) required for successful completion of key technical accomplishments ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD05d	...is consistent with the WBS ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD05e	...identifies the critical path of the program schedule ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD06	6. This project has a plan or plans for the performance of technical reviews with defined entry and exit criteria throughout the life cycle of the project ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD07	7. This project has a plan or plans that include details of the management of the integrated technical effort across the project (e.g., a Systems Engineering Management Plan or a Systems Engineering Plan) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD08	8. Those who perform systems engineering activities actively participate in the development and updates of the project planning ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD09	9. Those who perform systems engineering activities actively participate in tracking/reporting of task progress ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
PD10	10. The acquirer has provided this project with a Systems Engineering Plan ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code

11. This project has a Risk Management process that... (*Please select one for each*)

PD11a ...creates and maintains an accurate and up-to-date list of risks affecting the project (e.g., risks to cost, risks to schedule, risks to performance)
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

PD11b ...creates and maintains up-to-date documentation of risk mitigation plans and contingency plans for selected risks
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

PD11c ...monitors and reports the status of risk mitigation activities and resources
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

PD11d ...assesses risk against achievement of an event-based schedule
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

PD12 12. This project's Risk Management process is integrated with program decision-making
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Requirements Development, Requirements Management & Trade Studies

1. This project maintains an up-to-date and accurate listing of all requirements... (*Please select one for each*)

RD01a ...specified by the customer, to include regulatory, statutory, and certification requirements
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

RD01b ...derived from those specified by the customer
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

RD02 2. This project maintains up-to-date and accurate documentation clearly reflecting the hierarchical allocation of both customer and derived requirements to each element (subsystem, component, etc.) of the system in the configuration baselines
❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code	
	3. This project documents and maintains accurate and up-to-date descriptions of... (*Please select one for each*)
RD03a	...operational concepts and their associated scenarios ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD03b	...use cases (or their equivalent) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD03c	...product installation, maintenance and support concepts ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD04	4. This project has documented criteria for identifying authorized requirements providers to avoid requirements creep and volatility ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD05	5. This project has documented criteria (e.g., cost impact, schedule impact, authorization of source, contract scope, requirement quality) for evaluation and acceptance of requirements ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD06	6. The requirements for this project are approved in a formal and documented manner by relevant stakeholders ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD07	7. This project performs and documents requirements impact assessments for proposed requirements changes ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD08	8. This project develops and documents project requirements based upon stakeholder needs, expectations, and constraints ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD09	9. This project has an accurate and up-to-date requirements tracking system ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	10. For this project, the requirements documents are... (*Please select one for each*)
RD10a	…managed under a configuration control process ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code	
RD10b	...accessible to all relevant project staff ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD11	11. Stakeholders impacted by trade studies are involved in the development and performance of those trade studies ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD12	12. This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
RD13	13. Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	Interfaces, Product Structure & Integration
IF01	1. This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
IF02	2. Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	3. For this project, the product high-level structure is... (*Please select one for each*)
IF03a	…documented, kept up to date, and managed under configuration control ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
IF03b	...documented using multiple views (e.g. functional views, module views, etc.) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
IF03c	...accessible to all relevant project personnel ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code	
IF04	4. This project has defined and documented guidelines for choosing COTS product components ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
IF05	5. This project has accurate and up-to-date documents defining its product integration process, plans, criteria, etc. throughout the life cycle ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	Verification, Validation & Configuration Management
	1. This project has accurate and up-to-date documents defining... (*Please select one for each*)
V&V01a	...the procedures used for the test and verification of systems and system elements ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V01b	...acceptance criteria used for the verification of systems and system elements ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	2. This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that... (*Please select one for each*)
V&V02a	...defines entry and exit criteria for work products ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V02b	…includes training requirements for the reviewers ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V02c	...defines criteria for the selection of work products (e.g., requirements documents, test plans, system design documents, etc.) for review ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V02d	...tracks action items to closure ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V02e	...addresses identified risks and risk mitigation activities during reviews ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V02f	...examines completeness of configuration baselines ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code	
V&V03	3. This project conducts non-advocate reviews (e.g. reviews by qualified personnel with no connection to or stake in the project) and documents results, issues, action items, risks, and risk mitigations (*Please select one*) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	4. This project has accurate and up-to-date documents defining... (*Please select one for each*)
V&V04a	...the procedures used for the validation of systems and system elements ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V04b	...acceptance criteria used for the validation of systems and system elements ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V05	5. This project maintains a listing of items managed under configuration control ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V06	6. This project has a configuration management system that charters a Change Control Board to disposition change requests (*Please select one*) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V07	7. This project maintains records of requested and implemented changes to configuration-managed items ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
V&V08	8. This project creates and manages configuration baselines (e.g., functional, allocated, product) (*Please select one*) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	Project Performance: Earned Value Management
Perf01	1. This project creates and manages cost and schedule baselines ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
	2. Following are **five** statements about Earned Value Management Systems (EVMS). Do you agree or disagree that they describe this project?
Perf02a	Your customer requires that you supply EVMS data ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree

Analysis Data Code	
Perf02b	EVMS data are available to decision makers in a timely manner (i.e. current within 2 weeks) ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Perf02c	The requirement to track and report EVMS data is levied upon the project's suppliers ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Perf02d	Variance thresholds for CPI and SPI variance are defined, documented, and used to determine when corrective action is needed ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Perf02e	EVMS is linked to the technical effort through the WBS and the IMP/IMS ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
Perf03	3. When is the EVMS baseline updated? (*Please select as many as apply*) ❑ Only at contract initiation ❑ Whenever a contract change order or renewal is received ❑ Incrementally in rolling wave planning ❑ Whenever the project is reprogrammed due to a pre-determined cost or schedule variance ❑ At periodic intervals ❑ Other (Please describe briefly)
Perf04a. *Perf04b*	4. What are the current estimated cost at completion and the current estimated total duration for this project? (*Please specify for each*) Cost in US Dollars (*No dollar sign or commas please*) Duration in months

Analysis Data Code	
Perf05a. Perf05b	5. What is the projected variance at completion for the current contract baseline? (*Please specify for each, using + signs for any overruns and - signs for any underruns*) [ ] in US Dollars (*No dollar sign or commas please*) [ ] Duration in months
Perf06	6. What is the current cumulative (or final) EVMS Cost Performance Index (CPI) for this project? (*Please specify a number*) [ ]
Perf07	7. What is the current cumulative (or final) EVMS Schedule Performance Index (SPI) for this project? (*Please specify a number*) [ ]
Perf08a – Perf08j	8. What, if any, primary reasons do you attribute for the cost and/or schedule variance on your program? (*Please select the 1-3 most significant factors, if applicable*) ❑ Not applicable ❑ Mis-estimated ❑ Mis-understood ❑ Unfunded scope growth (requirements creep) ❑ Insufficient resources (staffing, etc.) ❑ Technical issues ❑ COTS/reuse issues ❑ Supplier issues ❑ Systems engineering activities insufficiently funded by program office ❑ Other reasons [ ]
	Other Performance Indicators

Analysis Data Code	
OPerf01a, OPerf01b	1. What percentage of available Award Fees have been received by this project? (*Please specify an approximate percentage for each* -- *without the percentage sign*) [ ] % -- in the current period [ ] % -- to date (i.e., in all periods)
OPerf02	2. Requirements are being satisfied and remain on track to be satisfied in the product releases as originally planned; they are not being deleted or deferred to later releases ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
OPerf03	3. Overall, this project is performing per the schedule established in the current IMS approved by the acquirer ❑ Strongly Disagree ❑ Disagree ❑ Agree ❑ Strongly Agree
OPerf04	4. The schedule of this project's critical path, when compared to the current IMS approved by the acquirer is... (*Please select one*) ❑ Greater than 6 months late ❑ Greater than 3 months late ❑ Greater than 1 month late ❑ Within plus or minus 1 month ❑ Greater than 1 month early ❑ Greater than 3 months early ❑ Greater than 6 months early
OPerf05	5. Does this project track reports of problems from fielded items? (*Please select one*) ❑ Yes ❑ No (*Please continue with question 8*)
OPerf06	6. Does the project conduct an engineering assessment of all field trouble re-ports? (*Please select one*) ❑ Yes ❑ No (*Please continue with question 8*)

Analysis Data Code	
OPerf07a – OPerf07d	7. The results of this engineering assessment feed into … (*Please select as many as apply*) ❑ Operational Hazard Risk Assessments ❑ Materiel Readiness Assessments ❑ System Upgrades Planning ❑ Other (*Please describe briefly*)
OPerf08	8. What performance indicators (beyond cost and schedule) have been particularly useful for managing your project? (*Please describe here*)
OPerf09	9. What other kinds of performance related information would have been helpful for your project or program, but was unavailable? (*Please describe here*)
OPerf10	10. What indicators do you use in your project or organization to determine systems engineering effectiveness? (*Please describe here*)
OPerf11	11. What indicators of systems engineering effectiveness are regularly reviewed across projects by higher level management? (*Please describe here*)

In Conclusion

Analysis Data Code	
Conc01	Is there anything else that you would like to tell us about your project or this survey? (*Please describe here*)

Thank you very much for your time and effort!

Before pressing the **Submit** button: Please be sure to use the **Save** button. Then use your browser's **File Save As...** to keep a copy of your completed questionnaire on your local computer. When doing so, do **not** change the default file type. You may wish to refer to the local copy if you need to recall your account name and password when the summary results become available.

Please press the **Submit** button **only** when you have completed the questionnaire fully to your satisfaction.

APPENDIX C Invitations to Participate

<date>

<SEEC POC Name>
National Defense Industrial Association
2111 Wilson Boulevard, Suite 400
Arlington, VA 22201

Telephone: <SEEC POC phone>

<FocalName>
<FocalOrganization>
<FocalAddress1>
<FocalAddress2>
<FocalCity>, <FocalState> <FocalZIP>

Thank you for taking the time to speak with me earlier. As noted in our conversation and my earlier email, I will serve as your primary point of contact for the Systems Engineering Effectiveness Survey being conducted by NDIA. This survey is of critical importance to both the Department of Defense and the US Defense industry.

The following enclosures to this letter provide details regarding the execution of this survey.

Enclosure 1: Letter from Lawrence P. Farrell, Jr. – This letter from the president of NDIA, describes the need for this study.

Enclosure 2: Non-Disclosure / Privacy Policy – Recognizing that we are asking for important data from your organization, we commit to protect this information to the best of our abilities. This document details the methods that we will use to ensure the confidentiality and security of the data that you provide.

Enclosure 3: Project Selection Instructions – This survey collects responses from individual programs and projects within your organization. This document details the instructions for selecting responding projects. This is a task that we ask you, our focal point for your organization to perform.

Enclosure 4: Letter to respondents – This is a letter that you may use to communicate a request to participate in this survey to the individual projects selected within your organization. It includes instructions for the respondent to access and complete the survey.

Enclosure 5: Terms and Definitions – This document contains definitions of what we mean by a project, a program, and an organization.

Please review these documents. I will call in a few days to discuss them further. In the meantime, if you have any questions or comments, please do not hesitate to contact me.

Thanks in advance for your support this survey. I look forward to collaborating with you on this important work.

Thank You

<SEEC POC Name>

Enclosures:

1) Letter from Lawrence P. Farrell, Jr.
2) Non-Disclosure and Privacy Policy
2) Respondent Selection Instructions
3) Letter to selected respondents
4) Terms and Definitions

Enclosure 1: Letter from Lawrence P. Farrell, Jr.

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

STRENGTH THROUGH INDUSTRY & TECHNOLOGY

2111 Wilson Boulevard, Suite 400
Arlington, Virginia 22201-3061
Tel: (703) 522-1820 • Fax: (703) 522-1885
Web page: http://www.ndia.org

The Voice of the Industrial Base

10-July-2006

Dear Colleague:

Your assistance is requested in the performance of a survey of critical importance to both the Department of Defense and the US Defense industry. The survey is being conducted by the Systems Engineering Division (SED) of the National Defense Industrial Association (NDIA) with the assistance of the Software Engineering Institute (SEI) and in coordination with the Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)).

The survey will elicit quantitative evidence on the conduct and performance effects of systems engineering activities. It is being distributed to project and program managers from a broad range of defense contractors. The analysis will focus on the statistical relationships between systems engineering activities and project performance. Such information heretofore has been sorely missing, and the results of this survey will be useful to both the Department of Defense and the US Defense industry. The survey results will enable you to benchmark the systems engineering activities of your organization against those of the defense industry. We urge you to arrange for the participation of project and program managers from your organization.

To assess the quantitative performance of the project, the survey asks for data that may be considered confidential and proprietary. Be assured that all information about your company will be held in the strictest confidence. NDIA has asked the Software Engineering Institute (SEI) to execute this survey. SEI is known to be an "honest broker," and has demonstrated the ability to collect and manage highly confidential data. All replies will be collected anonymously by SEI; no one, including us or your own management, will be able to tie specific replies to any individual, project, or organization. They will be accessible only to authorized SEI staff, and will not be seen by any other commercial or governmental organizations. There is no need to hide weaknesses or embellish strengths. The NDIA Systems Engineering Division, supported by SEI, will prepare a report after the results are received and analyzed by SEI. The results will be published only as aggregate statistics and excerpts and other non-attributable quotes. We will provide a copy to you as soon as it is ready.

We ask for your support of this survey effort, and your help in its execution. Specifically, we ask that you (or your designee):

- Identify projects within your organization to participate in this survey.
- Distribute the attached survey documents to those project managers, authorizing and encouraging them to participate.
- Follow up with the designated project managers to ensure their participation.
- Report to SEI the number of projects solicited, and the number responding.

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Our pre-testing has shown that most project managers will be able to complete the questionnaire in ranges from 30 to 60 minutes. You can see a non-executable copy of the questionnaire at https://seir.sei.cmu.edu/feedback/SystemsEngineering_Demo.htm. This site will become active on 10-July-2006.

Thank you in advance for participating in this important research. The results may influence the evolution of systems engineering practice, as well as government acquisition best practices and your own development work.

Sincerely, & Respectfully

Lawrence P. Farrell, Jr.
Lieutenant General, USAF (Ret)
President & CEO
National Defense Industrial Association

2

Enclosure 2: Non-Disclosure / Privacy Policy

1. This survey is being sponsored by the NDIA and will be executed via the Software Engineering Institute (SEI) web site. The SEI is an independent organization without direct ties to either acquirers or suppliers. It is known for maintaining confidentiality of information received from both government programs and defense contractors.

2. The questionnaire elicits no information identifying specific respondents, programs or organizations supplying the information.

3. All data will be submitted anonymously using randomly generated IDs via the SEI website. Since responses will be submitted electronically, it is inherently possible to trace these responses back to their source. The SEI will make no attempt to do so, and will quickly separate the response data from the random IDs in an untraceable manner.

4. Data provided for this survey will be used only for the stated purposes of this survey.

5. The data will be encrypted in transit via a secure socket layer and stored in encrypted format in a secure location within the SEI.

6. Only authorized SEI staff participating in this survey activity will have access to the raw data. Such access will be on a need-to-know basis for survey management purposes only. Raw data will not be made available to any other commercial or governmental organization.

7. Data presented in reports will not contain any information traceable to any person, project, or organization.

8. To further protect the confidentiality, all respondents will be solicited via proxy. The surveyors will contact proxies at each organization. The proxies will solicit respondents from within the organization. Neither the SEI nor the National Defense Industrial Association (NDIA) will know which programs or which project / program managers have been contacted. All communication with the SEI and NDIA will be via the proxies.

Enclosure 3: Project Selection Instructions

1. For purposes of this survey, the definition of a "project" or "program" is very broad.[1] Essentially, any synthesizing activity that is formally defined (by a contract, a specification, a memorandum of agreement, etc.), that is managed by a project or program manager, and employs generally accepted cost-accounting techniques may be considered a project. For a more comprehensive definition of the term "project" see Enclosure 5: Terms and Definitions

2. Be assured that the information that you supply will be held in strict confidence (see Enclosure 1: Non-Disclosure / Privacy Policy). Only authorized SEI staff will have access to the information supplied. The questionnaire does not solicit any information to identify the person, project, or organization responding. Furthermore, all information is collected anonymously. No one, including us or you will be able to tie specific replies to any individual, project, or organization. All information collected will be held in strict confidence by the SEI. Survey data will not be released to any other commercial or governmental organizations. The survey responses will be analyzed by the SEI. Only aggregate statistics, excerpts, and other non-attributable quotes, untraceable to any person, project, or organization, will be published.

   Please encourage the selected survey respondents to answer their questionnaires as candidly and completely as they can. The results will be useful to you, us and others only to the extent that the survey respondents are open and honest in their replies. Because the responses are anonymous, there is no need to hide weaknesses or embellish strengths.

3. Please identify appropriate respondents within your organization to participate in the survey. Potential respondents include project managers, program managers, deputy project managers, or deputy program managers for all projects within your organization. Both prime contracts and subcontracts should be included in the pool of potential respondents. Please don't "cherry pick" the most successful projects. It is equally important to include any distressed projects that may exist. Similarly, the pool of potential respondents should include all projects regardless of size, contract type, application domain, whether or not the system is precedented, or the maturity level of the organizational unit to which the projects report.

   We would like to receive responses from as many projects as possible. If you are unwilling or unable to provide responses from all of your projects, please select a random sample from them. One method of ensuring an unbiased sample is to create a complete list of all projects, and choose every "Nth" project from that list. For example, if you decide to provide 10 responses from a total of 100 projects, you would choose every 10th project (N=10). If you decide to provide 20 responses, you would choose every 5th project (N=5).

[1] Throughout this survey, the terms "project" and "program" will be used interchangeably

4. Report the number of projects chosen to the SEI via telephone at 412-268-9132 or via email at jelm@sei.cmu.edu.

5. Distribute the letter (Enclosure 4), as well as the Non-Disclosure / Privacy Policy (Enclosure 2) and the Definitions (Enclosure 5) to all selected survey respondents. Include your request or direction, for them to participate, and identify the project(s) for which they should respond.

   Please encourage the selected survey respondents to answer their questionnaires as candidly and completely as they can. The results will be useful to you, us and others only to the extent that the survey respondents are open and honest in their replies. Due to the anonymity of the response, there is no need to hide weaknesses or embellish strengths.

6. Please ensure that sufficient time will be provided for the project managers and their staff to complete the survey. Our pre tests have shown that completion of the questionnaire typically requires 30 to 60 minutes.

7. During the time established to collect responses, SEI will contact you or your designee to check on the survey status. When contacted by the SEI, please check with your selected respondents to see if they have submitted their responses, and report the number of responses submitted to the SEI (via telephone at 412-268-9132 or via email at jelm@sei.cmu.edu). Remember that the SEI will not know which specific projects have been selected to participate in the survey, so the SEI cannot remind them to complete their questionnaires; they must rely upon you to do that.

Enclosure 4: Letter to respondents

The following generic letter is to be distributed to all respondents as an attachment to a communication from the Industry Focal authorizing and encouraging the respondent to participate in the survey.

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION

STRENGTH THROUGH INDUSTRY & TECHNOLOGY

2111 Wilson Boulevard, Suite 400
Arlington, Virginia 22201-3061
Tel: (703) 522-1820 • Fax: (703) 522-1885
Web page: http://www.ndia.org

The Voice of the Industrial Base

July 27, 2006

Dear Survey Respondent:

Your management has asked you to participate in a survey that is being conducted by NDIA with the assistance of the Software Engineering Institute (SEI) and in coordination with the Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)). Along with other project managers from contractors throughout the defense industry, your replies will help provide trustworthy, quantitative evidence about the value of systems engineering activities in the acquisition and development of defense systems. Such information heretofore has been sorely missing, and the results of this survey will be of critical importance to both the Department of Defense and the US Defense industry.

Please complete the questionnaire as candidly and completely as you possibly can. The results will be useful to you, us and others only to the extent that you and the other survey respondents are open and honest in your replies. NDIA has tasked the Software Engineering Institute (SEI) to execute this survey. SEI is an independent organization without direct ties to either acquirers or suppliers. It is known for maintaining confidentiality of information received from both government programs and defense contractors. All replies will be collected anonymously by SEI; no one, including NDIA or your own management, will be able to tie specific replies to any individual, project, or organization. All replies will be held in strict confidence by SEI. They will be accessible only to authorized SEI staff, and will not be seen by any other commercial or governmental organizations. The results will be published only as aggregate statistics and excerpts and other non-attributable quotes. There is no need to hide weaknesses or embellish strengths. Our pre-tests have shown that completion of the questionnaire typically requires 30 to 45 minutes.

To complete the survey, complete the following steps:

1. Point your browser to

   https://seir.sei.cmu.edu/feedback/SystemsEngineering_Portal.asp

   where you will be issued a unique and randomly generated URL. This is YOUR URL; please record it – you will need it later when completing the survey. YOUR URL allows you to return and complete your questionnaire over multiple sessions if necessary, while maintaining your anonymity.

2. Point your browser to YOUR URL obtained in step 1 to access the survey questionnaire. Your user name (obtained from the YOUR URL) is pre-entered into the survey form. Enter a Password of your own choosing for the first question of the survey (To protect your anonymity, do not

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choose a password that identifies or hints at the identity of yourself, your program, or your organization.). This user name and password are your keys to completing the survey over multiple sessions, and will also provide access to the report on survey results.

3. Complete the survey. Click the 'SAVE' button(s) to save your work. When you have completed and saved the survey, save a local copy for yourself (using the /File/Save As command of your web browser) and click the 'Submit' button to securely transmit the file to the SEI.

As noted on the questionnaire, you will use the same user name and password to gain access to the summary report of the survey results when it becomes available. For at least a full year, the report will be made available only to those who fully complete a survey questionnaire. It will provide a baseline against which you can compare the performance of your project and organization with others in the industry.

The survey web sites will be active and available for downloading and submitting the survey from 24-July-2006 through 12-September 2006. Please respond promptly within these dates. Your management will contact you from time to time to remind you about the importance of this survey.

Thank you for participating in this research. The results may influence the evolution of systems engineering practice, as well as government acquisition best practices and your own development work.

Sincerely,

Lawrence P. Farrell, Jr.
Lieutenant General, USAF (Ret)
President & CEO
National Defense Industrial Association

Enclosure 5: Terms and Definitions

Definitions

A **PROJECT** or **PROGRAM**[2] is an integrated collection of efforts by a contractor team that produces deliverables to a customer under a specific contractual obligation.

- The contractor team is an organizational entity that may be an existing project, an integrated product team (IPT), a program, a division, or an assembly of members matrixed from more than one organizational unit. The contractor team has responsibility for the development or sustainment of one or more deliverables to a customer.
- Deliverables may be products (e.g. systems, subsystems, components, data) and/or services.
- A customer may be the government, another commercial organization, another division within your organization, another contractor team within your organization, etc.
- A contractual obligation is a commitment to perform a defined task in return for defined compensation. Contractual obligations are characterized by
  - a defined scope of work
  - a defined period of performance,
  - a defined cost
  - assignment to a defined executing organization
  - assigned responsibility for performance to a member of the contracting team.

  Contractual obligations may be defined via contracts with the government, contracts with other commercial organizations, work agreements within an organization, etc.

Typical Characteristics of a project include:

- Assigned project manager
- Defined schedule
- Defined budget
- A Work Breakdown Structure (WBS)
- Cost account management

Examples of PROJECTS include the following:

- Contractor ABC is under contract from the government to deliver the F-xxx aircraft.
- Contractor DEF is under contract from contractor ABC to deliver engines for the F-xxx aircraft.
- The Avionics Division of Contractor ABC is tasked by the F-xxx program to provide the navigation and communications avionics for the F-xxx. This effort has a defined scope, budget and schedule, negotiated between the F-xxx PM and the Avionics Division and documented in a Work Package Description and Memorandum of Agreement. The Avionics Division has assigned

[2] The terms "project" and "program" are used interchangeably throughout this survey.

a Program Manager for the effort. The Avionics Division has a WBS for and tracks costs vs. budget for the work.

The following is not an example of a PROJECT:

- A team of six engineers and designers within Contractor ABC is tasked to develop the wiring harness for the F-xxx aircraft. The team reports to one of the engineering leads reporting to the F-xxx PM. The wiring harness is an element of the F-xxx WBS, and costs for the development efforts are collected within the F-xxx accounting system.

A CONTRACTOR ORGANIZATION is an administrative structure within which (possibly many) projects or similar work efforts are organized under common management and policies.

- When thinking about your contractor organization, please answer for the unit to which the contractor team reports administratively, e.g., a site, division or department, not for a larger enterprise of which the contractor organization may be a part.
- Depending on the size and scope of the project, the contractor organization and the contractor team may be one and the same, and/or the same contractor organization may be responsible for more than one project.
- The contractor organization may be the prime contractor or a subcontractor. It may or may not have subcontractors of its own.

APPENDIX D Response Distributions for Individual Survey Questions

Per the terms of agreement with the survey respondents, the contents of the Body of the Report and Appendices A through C may be released publicly, subject to the copyright.

The contents of Appendix D may be released only to OSD, NDIA Management, and respondents to this survey until November 20, 2008. After said date, these restrictions are lifted, and Appendix D may be released publicly, subject to the copyright.

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